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# AGRICULTURAL ENGINEERING

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# Ventilating Stables with Electric Power[1]


By J. L. Strahan[2] and C. A. Marsh[3]


THE use of electricity in many instances has simplified the problem of the application of power to do farm work. It would seem that, of the many problems thus simplified, stable ventilation would profit most. However successful natural gravity ventilating systems may have been, there is no gainsaying the fact that they are subject to a number of serious objections. Large awkward flues must be installed; they are more expensive than anyone likes, whether they be manufacturer or user, and the season during which they render maximum service is limited by climatic variations.

The use of fans affects all these factors very materially. Flues are entirely eliminated, first cost is reduced more than half, and the benefits of ventilation are available the whole year through if desired. But the very simplicity of this solution of the ventilation problem constitutes a menace of no mean proportions.

Undoubtedly where a fan is installed, fresh air will always be available. But while air may be plenty fresh, it is not always properly tempered. Many of our older barns, in which no ventilation is installed, frequently freeze up during periods of extreme cold yeather. If a fan is going in this kind of a barn, the length of time it will stay frozen under comparable weather conditions will be increased in proportion to the amount of air it exhausts.

No, the problem is not quite so easily solved. Cutting one more hole in a barn already pretty much of a sieve is not going to provide better conditions just because a fan is placed in it. The problem is still unsolved. Its basic characteristics must still be considered. But now that we can use power to move air, it lends itself to a much more satisfactory solution. It is with the fundamental characteristics of the problem that I wish to concern myself at first, developing them in terms of the milking stable, and bearing in mind that, with different values for the constants used, the methods derived will be applicable to all other types of animal shelter buildings.

What is meant by ventilation? It is commonly considered as the process of passing air through an inclosed space. If this were all, it could be very simply accomplished by placing a fan in such relation to the enclosed space as to drive air through it. Unfortunately results from such simple methods have not proven entirely satisfactory when applied to stables, and this undoubtedly is largely because the fundamental purpose behind the use of the ventilating apparatus was not properly considered. Ventilation, whether of buildings housing humans or animals, has for its prime purpose the maintenance of a proper atmospheric environment both as to temperature and humidity. In the case of buildings housings humans, temperature control is effected by means of the installation of some heat-producing equipment, the ventilating apparatus being adjusted to cooperate with the heating apparatus in such a way as to maintain uniform temperatures and humidities.

There is no essential difference between the requirements for an animal shelter building and those for a building housing human beings. In both cases temperature control is imperative. The difference in the design problem, however, is wide because in the case of many animal shelter buildings, biological heat is already available in sufficient volume to provide means for proper temperature control.

Temperature control by means of ventilation in a stable definitely implies the presence of and the manipulation of heat in appreciable amounts and reasonably constant rates of production. It implies further the presence of factors tending materially to effect either favorably or adversely the temperatures produced by this heat. In other words, there are certain thermal elements of the problem which bear definite relations to each other. A consideration of these relations discloses the possibility for expressing them precisely in the form of a mathematical formula. The assumption upon which this formula is constructed is that all of the heat produced in a stable is dissipated in only two ways. The first is through air change. Air comes into the building at a low temperature and leaves it at a high temperature. Air change may be effected by means of a ventilation system or by means of leakage through the action of wind, but no matter how air change occurs it still results in a certain amount of heat loss. Assuming that no heat were lost by air change, there would still be loss by conduction through the walls, windows, doors and ceiling and radiation

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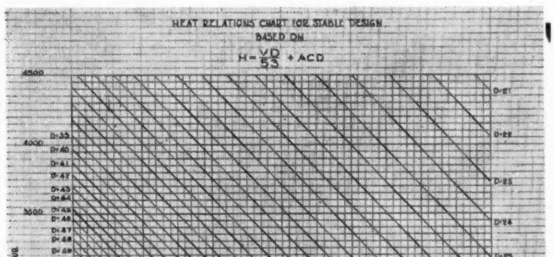


Fig. 1. The basic heat relations chart for stable design

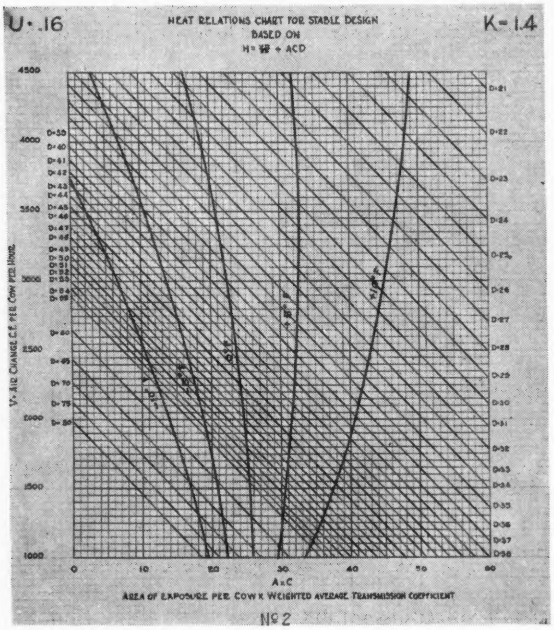


Fig. 2. The application of the basic heat relations chart to an assumed set of conditions

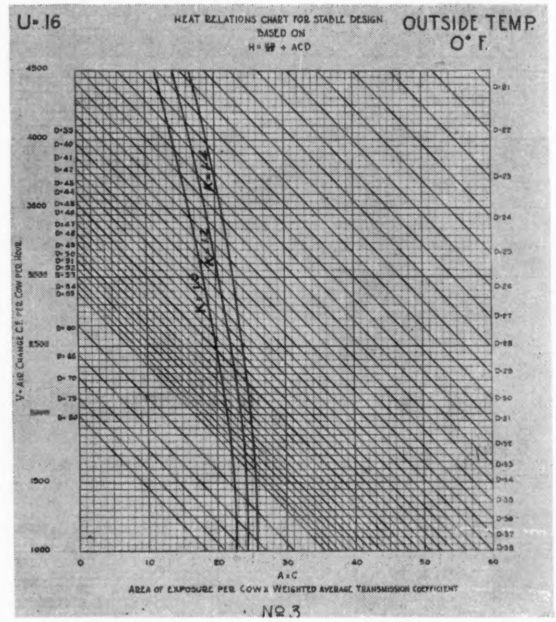


Fig. 3. This chart shows the relation between the condensation curves of three different types of wall surfaces at an outside temperature of zero degrees and a value for V of 0.16

from their outside surfaces. Heat produced, therefore, equals heat lost by ventilation plus heat lost by radiation and conduction. A formula expressing this situation may be stated as follows:

$$H=\frac{VD}{53}+ACD$$

in which H=total heat produced per cow in B.t.u. per hour

$\frac{VD}{53}$=B.t.u. lost by air change per cow per hour

ACD=B.t.u. lost by radiation and conduction per cow per hour.

Consider the quantity (VD÷53).

V equals the total volume in cubic feet of air moved through the room per cow. It makes no difference whether the air moves through ventilating flues, is forced through cracks in leakly construction or is propelled out with fans.

D equals the temperature difference through which the air is raised in its passage through the room. If the outside temperature is 5 degrees above zero and the inside temperature 45 degrees, the value for D would be 40 degrees. For want of a better term, we have called this temperature difference the "heating duty," as being the job imposed upon the cows of maintaining a proper temperature.

The number "53" equals the number of cubic feet of air that can be raised one degree Fahrenheit by one B.t.u. of heat. The specific heat of air at stable temperatures (from 35 to 50 degrees Fahrenheit) is variable and is such as to cause this value to range between 53.3 at 32 degrees and 52.78 at 50 degrees, both assumed at an atmospheric pressure of 14.7 pounds per square inch. The effect of this variation on the final solution of the problem is so slight, however, as to be negligible.

The following example illustrates how the quantity (VD ÷53) can be determined in any specific instance. Suppose a room 36 by 100 feet by 8 feet high housing 50 cows is provided with four changes of air per hour. A total volume of 115,200 cubic feet of air will be handled each hour, or 2304 cubic feet per hour per cow. Suppose this air is raised through 40 degrees, namely, brought in at 5 degrees above zero and expelled at 45 degrees. Then the number of B.t.u. lost would equal VD÷53, or [(2304 x 40) ÷ 53]=1739.9 B.t.u.

Now consider ACD. A equals the sum total per cow of all areas of walls, windows, doors, and ceilings (also floors at times) exposed to heat loss through radiation. Its value is arrived at by computing the total superficial exposed area of the room to be ventilated and dividing this by the number of cows housed.

C equals an average weighted coefficient of heat transmission stated in terms of B.t.u. per square foot per degree of temperature difference per hour. In order to explain the term "average weighted coefficient," consider this situation. Suppose the room mentioned above is so constructed as to present the following areas to exposure and consequent heat loss, and suppose the construction to be such that the insulating value of the areas are accurately expressed by the coefficients indicated:

| Material | Area | Transmission Coefficient |
|---|---|---|
| Concrete wall | 254 sq. ft. | 0.64 |
| Frame wall | 1596 " " | 0.18 |
| Windows (storm sash) | 200 " " | 0.55 |
| Doors | 126 " " | 0.50 |
| Ceiling | 3600 " " | 0.20 |

The B.t.u. lost by radiation if the outside temperature is 5 degrees above zero and the inside is 45 degrees, will be shown in the following table:

**B.t.u. Lost by Radiation**

| Construction | Area, sq. ft. | Transmission coeff. | D | Heat loss per degree | Total heat loss |
|---|---|---|---|---|---|
| Concrete Walls | 254 | 0.64 | 40 | 162.56 | 6502.4 |
| Wood Walls | 1596 | 0.16 | 40 | 255.36 | 10214.4 |
| Windows | 200 | 0.55 | 40 | 110.00 | 4400.0 |
| Doors | 126 | 0.50 | 40 | 63.00 | 2520.0 |
| Ceiling | 3600 | 0.20 | 40 | 720.00 | 28800.0 |
| Totals | 5776 | | | 1310.92 | 52436.8 |

$$\text{Average weighted coefficient} = \frac{\text{total heat loss per degree}}{\text{total area}} = \frac{1310.92}{5776}$$

$$C = 0.227$$

The room described above is assumed to house 50 cows, The total area exposed to heat loss is 5776 square feet. Therefore, the area per cow (A) is

$$A = \frac{5776}{50} = 115.5$$

Substituting C=0.227

$$AC = 115.5 \text{x}.227 = 26.22$$

$$ACD = 26.22 \text{x} 40 = 1048 \text{ B.t.u. per cow per hour}$$

This represents heat loss by radiation and conduction from this stable per cow unit per hour under these climatic and temperature conditions.

Referring to the discussion of the quantity (VD÷53), the heat loss was computed on the assumption that four changes of air would be made per hour handling in all 115,200 cubic feet per hour. If fifty cows are housed in the building this amounts to 2304 cubic feet per cow per hour, and raising this much air through 40 degrees would require 2304x(40÷53)=1739.9 B.t.u.

If these values, namely, 1739.9 for (VD÷53) and 1048.8 for ACD, are substituted in the original formula, then

$$H = 1739.9 + 1048.8 = 2788.7 \text{ B.t.u. per hour}$$

It is evident that, if these temperature conditions (45 degrees inside at 5 degrees above zero outside) are to be maintained while four changes of air per hour are produced by the ventilating system, a cow must produce slightly under 2800 B.t.u. per hour. Work by Armsby and Fries at the Pennsylvania State College in animal calorimetry indicates that only the larger milking cows in high milk production will produce heat at this rate. On the other hand, practical experience of our own has definitely demonstrated that temperature differences greater than those indicated in this discussion can be maintained without appreciably lowering what we have come to consider adequate ventilation standards. We have therefore assumed that one unit of animal heat production will be 3000 B.t.u. per hour. (One of the workers at the Institute of Animal Nutrition, Pennsylvania State College, has stated that a concentration of 50 parts $CO_2$ per 10,000 does not in his estimation indicate especially undesirable ventilation conditions. It will be remembered that King's maximum permissible $CO_2$ concentration was about seventeen parts per 10,000.)

From these observations and until further research brings to light new facts only one inference can be drawn, and that is, whereas King originally maintained that 3500 cubic feet of air per cow per hour was the proper rate of air flow through stables and led us to infer through his writings that this rate of flow should be constant, actual practice and observation indicates that there is no one standard rate of air flow that is desirable or even possible under all conditions, but that it must and should be reduced with reductions in outside temperature to the point where the animal heat produced will be sufficient to maintain a reasonable stable temperature, in the face of unavoidable but reducable radiation losses. It is becoming increasingly evident that the purpose of ventilation is not to maintain a certain standard of chemical purity in the air, but that it is to maintain the physical environmental characteristics of temperature and humidity as constant as possible at the point of greatest biological efficiency.

If our object is to maintain a uniform temperature and if the means for doing this is to consist of some device for varying air flow through the building, it is highly desirable that we know just what effect different volumes of air flow through a building under different outside temperature conditions will have upon the inside temperature. In order to visualize the relations between these factors, we have constructed a chart 1 (Fig. 1) on the basis of an algebraic modification of the original Formula 1.

$$H = \frac{VD}{53} + ACD \quad \text{..............................} [1]$$

$$53H = VD + 53ACD$$

$$VD = 53H - 53ACD$$

$$V = \frac{53(H - ACD)}{D} \quad \text{..............................} [2]$$

The chart consists of a series of parallel diagonal lines obtained by plotting air volume against values of AC. In making the computations different values of AC are assumed for a given value for D and the value for V is determined by substituting in Formula 2. Thus, assume AC to equal 30 and D to equal 45. Then

$$V = \frac{53\,[3000 - (30\text{x}45)]}{45} = 1943 \text{ cubic feet per hour per cow}$$

Also assume AC to equal 10 and D to equal 45. Then

$$V = \frac{53(3000 - 450)}{45} = 3003 \text{ cubic feet per hour per cow}$$

Each result states the volume of air that must be passed through the stable for which the AC value was assumed in order to maintain the temperature difference, or D, of 45 degrees. But three determinations for a given value of D are necessary to indicate that the relation is properly expressed by a straight line curve.

By substituting other values for D, we can in like manner obtain data from which all other diagonal lines may be plotted.

This chart clearly indicates that, in any given barn, temperature can be maintained by varying the rate of air change with outside temperature changes. In a stable having an AC characteristic of 30, if we wish to hold an inside temperature of 45 degrees when the outside temperature is zero, we must restrict the air flow to approximately 1950 cubic feet of air per minute. However, if the AC characteristic of this stable is reduced to 20, either by adding insulation, which results in reducing the value of C, or increasing the animal population which results in a reduction of the value for A, then a temperature of 45 degrees can be maintained at outside zero, even though approximately 2465 cubic feet per hour per cow pass through it. In general terms the more animals there are in the stable and the better it is insulated, the more air we can pass through it without lowering the inside temperature.

It is to be observed that an inside temperature of 45 degrees can be maintained in a stable with an AC characteristic of 30 even though 2950 cubic feet per hour per cow is passed through, providing the outside temperature is not lowered below 10 degrees above zero. In other words, by raising the outside temperature and holding the inside temperature constant, we have now reduced the value for D. Thus in a given stable, to hold a constant inside temperature, air flow must be varied with outside temperature variations, restricting the flow as the outside temperature drops and increasing it as outside temperature rises.

We have here a means for determining the exact design characteristics of any stable if we know (1) the winter conditions in the locality in which it is built, (2) the optimum temperature which should be maintained for the most efficient production of milk, and (3) a standard criterion for proper ventilation performance. If this stable is to be built in a climate where the outside temperature will be of a probable maximum severity represented by 5 degrees above zero, and if the optimum stable temperature is to be 45 degrees, we must design the stable so that a temperature difference of 40 degrees can be maintained, without too severe restriction of air flow. That last is an important phrase. Just exactly what constitutes a dangerous restriction of air flow must be assumed be-

fore we can proceed logically to design. Fortunately we have one criterion for adequate ventilation which is easily recognized and which can be mathematically expressed and precisely considered. It is generally admitted that a ventilation system should not only control temperature variations within a small limit, but it should also prevent condensation on interior stable surfaces. Our experience up to the present leads us to assert that it is safe to assume dangerous restriction of air flow to be that at which condensation will begin to show. At this point the relative humidity of the air in the stable is at 100 per cent at the temperature of the inside surface involved. It is not a difficult proposition to determine just how much air must pass through the room to remove moisture assuming that we know how much moisture is produced and how much is brought into the room with the fresh incoming air. Of course this volume of air will vary with other important conditions which effect condensation, namely, the heat transmission and surface characteristics of the materials of construction.

With the idea in mind of determining what the limits of air flow regulation will be in any particular case to prevent condensation, we have added other lines to the chart (Fig. 1). To do this we have had to assume that moisture production by the cows is a constant factor. Armsby and Kriss in their article, entitled "Some Fundamentals of Stable Ventilation," published in the July 1921 number of AGRICULTURAL ENGINEERING, state that Holsteins producing thirty pounds of milk give off 8477 grams of water vapor in 24 hours. We have used this figure but have reduced it to a statement of pounds of moisture produced per hour. This value is 0.7869 pounds, or about 1½ pints per hour. The only way this moisture can be removed is through ventilation. If ventilation is to be restricted within such a range as will be required to maintain temperature control, the ability to remove moisture will be likewise limited, hence the degree to which relative humidity can be lowered will definitely be determined by outside relative humidity, temperature difference and the number of cows in the stable. Obviously there must be a point beyond which it will not be possible to restrict ventilation, if moisture condensation is to be avoided under any definite set of insulation and structural conditions. It is this danger point which we have attempted to represent graphically by a chart (Fig. 2).

Because insulation and structural conditions affect this part of the problem, it will be desirable to discuss the theory of heat transmission briefly to lead up to the discussion of the method for plotting the condensation lines on the chart. Any wall separating two areas of different temperatures is subjected to a thermal pressure whereby nature attempts to equalize the temperatures on the two sides, heat passing from the warmer to the colder area. In passing through a homogeneous wall, heat must first impinge on the warm surface; second, it must be transmitted through the body of the material, and third, it must radiate off the cold surface. Experiments have been conducted on a number of different materials to determine exactly how fast heat will impinge on or radiate from the surface and how fast it will pass through the material. These rates have been expressed as coefficients stating the B.t.u. which will pass per unit of area per hour per degree of temperature difference. In still air it is our understanding that the rate of impingement and the rate of radiation is expressed by the same coefficient. When air is moving over the surface, this coefficient increases. The coefficient for an ordinary wood surface on the inside of a wall, which is subjected to the passage of slow air currents which might be produced by heat convection, has a value of approximately 1.4. The same surface on the outside of the wall subjected to a wind of 15 miles per hour would lose heat at a rate expressed by the coefficient 4.5. The passage of heat through the material itself is practically constant for any given material, and the total heat transmission will vary with the thickness of the material.

It is evident then that the total heat loss through a wall can be expressed by a coefficient which takes into consideration not only the transmittance through the material itself but also the surface coefficients as described above. This total transmission coefficient we have called U in conformance with the usual practice.

The coefficients express the heat loss value of the material. Because insulating value is the same as the reciprocal of the heat loss value, U can be mathematically determined by taking the reciprocal of the sum of the reciprocals of all of the individual coefficients involved in the construction. Thus a stud wall ceiled on the inside over ½-inch Celotex, with paper and drop siding on the outside, would have a value for U of 0.188. The following table states the values for the various coefficients, both surface and transmission, from the inside air to the outside air and the computation which follows illustrates the method for computing the total insulation value of the wall:

| Material | C | $K_1$ | $K_2$ |
|---|---|---|---|
| Wood | 1.00 | 1.4 | 4.5 |
| Celotex | .34 | | |

$K_1$=coefficient for surface unexposed to wind
$K_2$=coefficient for surface exposed to wind

$$U=\frac{1}{\frac{1}{K_1}+\frac{.625}{Cw}+\frac{.5}{Cc}+\frac{1}{K_1}+\frac{1}{K_1}+\frac{.875}{Cw}+\frac{1}{K_2}}$$

$$U=\frac{1}{.714286+.625+1.441+.714286+714286+.875+.2222}$$

$$U=\frac{1}{5.30608}=00.188$$

This method has been checked for many materials and found to be accurate for all practical purposes. For some materials, however, a close check has not been found. Information is needed on different styles of building tile. Variations in mix seem to affect the heat transmission for concrete. Thus, accurate determinations for the value of U for this class of construction is not at present possible.

Consider again the matter of moisture condensation on the inside wall surface. Condensation occurs only when the relative humidity of the air is at 100 per cent and when that air touches a surface whose temperature is cooler than its own. The temperature of the inside

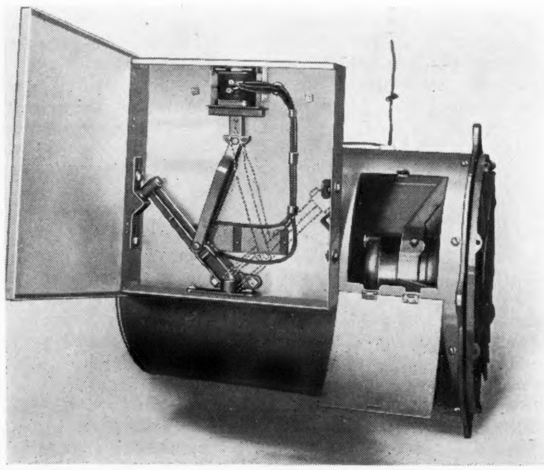

Fig. 4. The exhaust unit of the Louden electric ventilation system

surface of a wall separating two areas of unequal temperature will always be somewhat colder than the air on the warm side. The exact amount colder will be determined by the relations existing between total temperature difference, the values for U, and the inside surface coefficient.

Thus the temperature drop between inside air and inside wall surface is to the temperature drop between inside and outside air as the reciprocal of the inside surface coefficient is to the reciprocal of the total wall transmission coefficient. The proportion is expressed as follows:

$$T_1 - T_2 : T_1 - T_3 = \frac{1}{K_1} : \frac{1}{U}$$

This relation can be algebraically transposed to get the value of $T_2$ in terms of all other factors. Thus

$$T_2 = T_1 - \frac{U(T_1 - T_3)}{K_1} \quad \ldots\ldots [3]$$

But $T_1 - T_3$=temperature difference, and is the same as D in the discussion above. Substituting D for $(T_1 - T_3)$ the formula becomes

$$T_2 = T_1 - \frac{UD}{K_1} \quad \ldots\ldots [4]$$

This formula has been used to compute the inside surface temperature at varying outside temperatures, with the ultimate object of determining just how much moisture can safely be allowed to remain in the stable per cubic foot without danger of condensation.

If the amount of moisture that may remain without danger of condensation is known, then the amount of moisture that must exist in the outgoing air is known because this is one and the same thing. Weather bureau reports provide data on the average winter outside relative humidities. The amount of moisture that will be brought into the stable in each cubic foot of incoming fresh air under any outside temperature conditions can then be accurately determined from psychrometric tables. The difference between what comes in and what goes out per cubic foot represents that part of the moisture produced by the cow that must be removed by the ventilation system per cubic foot of air. The amount of moisture produced per hour by the cow is known or assumed. If the total amount of moisture produced per cow per hour is divided by the amount that one cubic foot of air can carry out, the total air change in cubic feet per cow per hour will result.

This is the amount of air that must be passed through the stable if the relative humidity is to be held at the danger point for the particular wall and surface co-efficient involved, and represents the point beyond which it will be unsafe to restrict ventilation.

For the purpose of demonstration, we have assumed a set of conditions and plotted a series of curves (Fig. 2). The conditions for which these curves are plotted are as follows:

1. $U = 0.16$
2. $K_1 = 1.4$
3. Outside relative humidity=80 per cent
4. Outside temperatures vary in increments of 5 degrees, from 10 degrees below zero to 10 degrees above zero.

The typical series of computations for condensation lines in the accompanying table represent conditions at 5 degrees above zero. Column 1 is inside stable temperature. Column 2 is the value for D, or the temperature difference between inside and outside. Column 3 is the computed temperature of the inside wall surface on the basis of Formula 4, $T_2 = T_1 - UD \div K_1$). Column 4 states the number of pounds of water that can exist in one cubic foot of air when saturated at the temperature of the inside wall surface. Column 5 represents the pounds of moisture in one cubic foot of incoming air at 80 per cent relative humidity and 5 degrees above zero. Column 6 represents the pounds of moisture removed by one cubic foot of air and is computed by substracting Column 5 from Column 4. Column 7 states pounds of moisture produced per cow per hour. Column 8 states the volume of air in cubic feet per hour per cow needed to remove excess moisture and is obtained by dividing the values in Column 7 by those in Column 6.

Referring to the chart (Fig. 2) the data in Column 8 has been plotted as follows: On the line representing a temperature difference or value for D of 25, we have plotted an air volume of 4653 cubic feet. This point extends above the upper limits of the chart. On the line D=30 we have plotted an air volume of 3541 cubic feet. On line D=35 we have plotted 2825 cubic feet, and so on down to the line D=60 where we plotted a volume of 1088 cubic feet. The line on the chart marked 5 degrees above zero results from connecting all of these points.

Similar computations have been made assuming outside temperatures of —10, —5, 0, and +10 degrees and the lines plotted in the same way.

Consider the line 5 degrees above zero and consider also a vertical line representing a barn with an AC characteristic of 32. The condensation line crosses this vertical AC line at an air volume of around 2300 cubic feet. If air change through that stable were restricted below 2300 cubic feet in an attempt to maintain a temperature difference higher than about 40 degrees, condensation would begin to appear. To prevent condensation, it would be necessary to increase air flow to above 2500 cubic feet and allow the temperature difference to drop to 35 or 36 degrees, thus maintaining an inside temperature of around 40 degrees. At this outside temperature of 5 degrees above zero, it would be possible to put air through the stable very rapidly, even more than 4500 cubic feet per hour per cow, reducing the temperature difference to very nearly 25 degrees without danger of condensation. Of course this would not be allowed to happen as freezing temperatures are always avoided. It is interesting to note, however, that, if our original constants are anywhere near accurate, control of condensation in this barn cannot be maintained if the temperature is raised by restricting air flow below the point first mentioned, namely, about 2350 cubic feet.

Consider now what would happen if we should modify the design of the building to reduce the AC characteristic from 32 to about 30. This would require the addition of but a very small amount of insulation or the reorganization of the plan to include a very few more animals and thus to reduce the area of exposure per animal to heat loss a comparatively small amount. In this case we could restrict air change, instead of down to 2300 cubic feet, well down to 1250 cubic feet before danger of condensation would be reached. At this restricted rate of air change, we could maintain a temperature difference of 55 degrees, or an inside temperature of 60 degrees, whereas before we were able to maintain a maximum inside temperature of not more than 45 degrees. Thus a very slight modification in design is required to produce a very large increase in the possible range of permissable temperatures—and the opportunity for control is measurably increased.

The same line of reasoning can be applied to the lines representing 5 degrees below zero and zero, except that here more and more modification of stable design is necessary to produce smaller increments of control increase. In other words, as outside temperatures become more severe, the matter of stable design for condensation control becomes more critical.

It is particularly interesting to note that at low outside temperatures, large temperature differences can be maintained without danger of condensation only providing that the design of the barn, as represented by the AC characteristic, is such as to prevent heat losses. Thus, theoretically, a barn with an AC characteristic of 26 would begin to show condensation as soon as outside tempera-

tures dropped to about one degree above zero and it would be impossible, through restricting air flow, to raise the temperature to the point where condensation would be eliminated. However, a stable having an AC characteristic of 24, only two points lower, could maintain an inside temperature of 45 degrees when the outside temperature is zero without danger of condensation, and at this outside temperature could run the temperature up practically indefinitely by still further restricting flow without danger of condensation.

It must be kept in mind that these particular condensation curves apply only when the value of U is 0.16 and K is 1.4. Computations based on other values for these factors result in different locations for the condensation curves on the base chart. When U is high, the inside wall surface temperature becomes low. The result is to move the condensation line to the left on the base chart, indicating that the AC value must be lower to avoid condensation. However, if C is higher (as it must be if U is high), then A must be very much reduced in order to make AC smaller. It will be seen that A will soon become so small as to present impossible conditions of design. That many cows simply cannot be squeezed into the building. The alternative is to add artificial heat. A very interesting study can be made to work out specifications for the addition of heat to meet any set of conditions. Assume the addition of 3000 B.t.u. per hour to be equivalent to adding one animal unit to the capacity of the barn. The addition of one or more such units will reduce the area of exposure, or A, and thus reduce AC, and hence change the position of the design line favorably (to the left) on the chart (Fig. 1). Adding heat by adding animals also adds moisture. But adding artificial heat does not add moisture. Instead it will reduce the unit production of moisture in the stable. This will tend to move the condensation lines to the right on the base chart thus adding to the net gain in adaptability of the design to conditions.

There must be an economic balance between insulation to conserve animal heat and the addition of heating apparatus to supplement it. So long as it is physically possible, by conserving natural heat, to maintain proper conditions the insulation method would appear to be the better because thereafter there would be no operating expense. On the other hand, a heating plant takes fuel and fuel takes money.

Our experience is that insulation is to be preferred to artificial heat where it is possible, thereby to hold the AC characteristics of the design below 30 in all but extremely cold climates. Frequently in the very cold climates the only completely satisfactory solution is to supply some artificial heat, the alternative of course being to suffer some low temperatures in the stable during the very coldest periods.

Another interesting fact that appears upon further consideration of these relations is the effect of variations in the value for K, or the inside surface coefficient, on this problem of condensation. It has been observed that smooth inside surfaces seem to show condensation more quickly than comparatively rough ones. In our own experience we have observed this on smooth plaster walls whereas apparently similar conditions did not produce condensation on painted wood walls. Another chart (Fig. 3) has been constructed to show the relation between the condensation curves of three different types of wall surfaces at an outside temperature of zero and a value for U of 0.16. Computations similar to the one described for condensation lines on the chart were made with values of K of 1.0, 1.2 and 1.4. The line for K=1.4 is identical with the line on the first chart (Fig. 2) marked "O°F." Except for the surface characteristic, the three lines represent walls of exactly the same heat loss characteristics. In other words, the value for U is 0.16 in each case. The rough wall is represented by K=1.4 and the smooth wall by K=1.0. If we had a stable in which AC

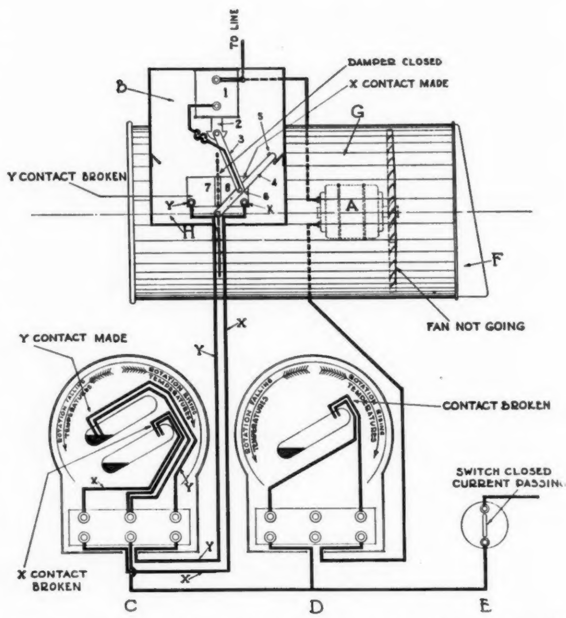


Fig. 5. This diagram illustrates the operation of the automatic damper control hook up of the Louden electric ventilating system

equalled 20, the smooth wall would begin to show condensation when the temperature difference dropped to 45 degrees with a total possible air change of 2475 cubic feet. However, the same wall in the same barn, but with an inside surface of wood, would withstand condensation until the outside temperature warmed up to where D=34½ degrees (approximately) with a maximum possible air flow of 3750 cubic feet.

I have discussed only a few of the many interesting phases of the subject that might be uncovered by further consideration and study of these basic heat relations. I do not hold that the results of this preliminary study are quantitatively accurate. In fact I know from actual field experience that they are not. I am convinced, for instance, that heat and moisture production are not constants but variables. The chart was constructed on the assumption that they are constants because that is all we have at present to go on. The use of variables instead of constants will change the location and relations of lines on the chart and will undoubtedly account for discrepancies that now seem to exist between theoretical and actual performance. But be that as it may, there can be no question that these relations do exist substantially as indicated in this discussion, that qualitatively our arguments are sound. It therefore seems most desirable to approach the problem of equipment design with these fundamentals distinctly in mind for careful consideration.

Accordingly we have brought on the market an electric ventilation system, the design of which is based on the following three premises:

1. The purpose of ventilation in an animal shelter building housing producing livestock is to maintain as nearly as possible a uniform condition of temperature and humidity.

2. This end can be attained only by closely and automatically relating the rate of air flow through the ventilated room to the temperature of the incoming air in such a manner as to restrict the flow as this temperature falls.

3. The amount of heat produced by the stock can be used to maintain proper temperature only if the construction and insulation of the barn is properly related to the climatic conditions to be expected in the location where it is built.

The complete system consists of an exhaust unit as shown in Fig. 4, and a series of controlled intake flues.

The exhaust unit consists of a fan and motor housed in a short duct and controlled by a thermostat set to break the circuit when there is danger of freezing in the stable. In addition there is an automatically operated damper set in the duct behind the fan which when closed restricts the flow of air approximately one-half of what it is at free delivery. The device for opening and closing the damper is mounted on the end of the damper shaft and is actuated by a double-acting thermostat set at the desirable room temperature. An automatic louvre is placed over the exhaust opening on the outside of the building which closes when the motor is not in operation to keep the weather away from the fan.

Fig. 5 illustrates the operation of the automatic damper control hook up. A is the fan and motor set in the duct G. B is the control mechanism which operates the damper H. C is the double-acting thermostat which operates the damper control. D is a single-acting thermostat operating the fan motor. E manually controls the system. F is the automatic louvre.

The thermostats C and D are the mercoid type which make or break an electric circuit by tipping a drop of mercury against or away from terminals set in one end of a glass tube. These tubes rotate in a vertical plane clockwise with rising temperatures and counter clockwise with falling temperatures.

The fan motor is connected in the circuit with thermostat D. In Fig. 5 the temperature is such as to cause a counter clockwise rotation, breaking the circuit and stopping the motor.

At the same time thermostat C which is connected in the circuit with the damper control device is also equally rotated counter clockwise. The upper bulb makes a connection while the lower one breaks one.

Consider now the damper control device. The prime mover in this instrument is a solenoid mounted on the upper side of a steel box in such a way that the head is pulled up when the circuit is made and falls out by gravity when it is broken. Attached to the head is a clevis (3) which pulls on the lever (4) to which it is connected with a pin connection at its lower end. The lever is keyed at its lower end to the shaft of the damper. Here the damper is shown in a vertical position. A rubber bumper (5) is attached to the enlarged upper end of the lever (4) to quiet the noise of impact at the end of the stroke.

A carbon contactor or electrode (6) is attached at the lower end of the clevis and is insulated away from the metal parts of the mechanism. This electrode makes contact with two brass plates (7 and 8) which are separated from each other and from the steel housing with insulating fiber. Each plate is provided with an attachment for wire connection (X and Y).

Consider now the thermostat C. Circuit Y is connected in the thermostat but is broken at the plate of the controller (7). Circuit X is broken in the thermostat but connected at the plate of the controller (8). Assuming that the switch E is on, permitting the system to operate, then when the temperature is low no current can pass through the solenoid and the damper remains closed. However, as soon as rising temperatures cause sufficient clockwise rotation to tip the mercury in C to the other ends of the tubes, immediately circuit X is closed both in the solenoid and at the plate, and the solenoid is energized causing its head to pull up on the linkage connected to the damper shaft. The circuit remains closed until the electrode slips by the right-hand edge of the plate (8), at which time it (the circuit which caused the action) is broken. The instant this happens gravity causes the head to fall, and its weight is sufficient when added to the momentum already imparted to the lever, to force the lever to complete its 90-degree arc of travel. As the damper is attached to the shaft 45 degrees away from the lever, its second position will be horizontal.

It will be observed that, when the clockwise rotation of thermostat C caused the circuit X to close, it also at the same time opened circuit Y. Furthermore when the lever arm with its electrode passed to the left-hand plate (7), this same circuit Y was closed at the controller. It is therefore ready to receive current immediately upon sufficient counter clockwise rotation in the thermostat under lowering temperatures to close Y in the bulb. The operation is then just reversed and the damper is shut.

Objection to this method of controlling the rate of air flow will immediately be made on the score of overloading the motor when subjecting the disk fan to highly variable static pressures. Ordinarily this would be a perfectly valid objection, but in this instance it is not because the characteristics of the fan we are using are such that subjecting the motor to 100 per cent maximum static head will increase the actual consumption of power so small an amount as to be practically negligible. Of course increasing the head rapidly decreases delivery. This, however, is a simple matter of design having to do with the calibration of the damper.

You have already inferred how we expect this system to operate. We will set the double-acting thermostat at the desired room temperature, and the other at the freezing danger point, perhaps 38 degrees above zero. Under normal operating conditions the damper will be open and fan going. Our design will provide for upwards of 4000 cubic feet per hour per cow. When the temperature of the room is reduced under this rate of flow to a degree or two below what we want to hold, the damper will automatically close and the flow will be reduced to something less than 2000 cubic feet per cow. Under ordinarily severe winter conditions this situation will last for a comparatively short time until the cows

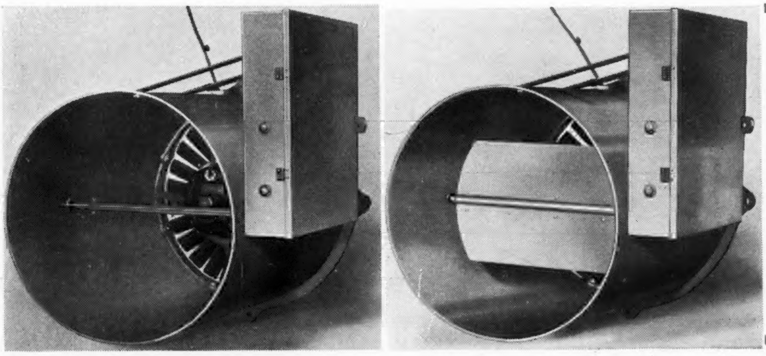

Fig. 6. (Extreme left) A view from the rear of the exhaust unit of the Louden electric ventilating system (Fig. 4) showing the damper open. Fig. 7. (Left) The same view as Fig. 6, with the damper closed

**Typical Computations for Condensation Lines**
(For 5 degrees above zero Fahrenheit)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Inside temperature, degrees | D | $T_2$ | Lb. moisture per cu. ft. air saturated at temperature $T_2$ | Lb. moisture per cu. ft. air at 5° F. and 80% relative humidity | Lb. moisture removed per cu. ft. air (produced by cows) | Lb. moisture produced per cow per hour | Volume of air, cu. ft. per hr. per cow, required to remove excess moisture |
| $T_1$ | $T_1-T_3$ | $T_2=T_1-\frac{UD}{K}$ | Psychrometric tables | Psychrometric tables | Column 4 minus column 5 | Armsby & Kriss | Column 7 divided by column 6 |
| 30 | 25 | 27.1425 | .000231173 | .0000631168 | .0001680562 | .77869 | 4453 |
| 35 | 30 | 31.5710 | .000282990 | .0000631168 | .0002198732 | .77869 | 3541 |
| 40 | 35 | 36.0000 | .000338720 | .0000631168 | .0002756032 | .77869 | 2825 |
| 45 | 40 | 40.4280 | .000403030 | .0000631168 | .0003399132 | .77869 | 2279 |
| 50 | 45 | 44.8565 | .000477900 | .0000631168 | .0004147832 | .77869 | 1877 |
| 55 | 50 | 49.2850 | .000564940 | .0000631168 | .0005008232 | .77869 | 1554 |
| 60 | 55 | 53.7135 | .000665560 | .0000631168 | .0006024432 | .77869 | 1292 |
| 65 | 60 | 58.1420 | .000778690 | .0000631168 | .0007155732 | .77869 | 1088 |

NOTE: Values in Column 8 are plotted on D lines in Column 2 to get the condensation line on the chart (Fig. 2).

have a chance to raise the temperature to a few degrees above the desired point. Then the damper will open again. Thus we have a means for holding temperature within a reasonably narrow range of variation without ever cutting out the ventilation. In most sections in Zone 2 and southern Zone 1, we are expecting the fan to operate 24 hours a day. It is only in extreme weather that danger of freezing will shut off the fan, assuming of course that the stable is properly built for heat conservation.

In closing, the most important points brought out in this discussion seem to be as follows:

1. So long as no artificial heat is used, and if temperature control is the important function of a ventilating system, then the barn design and construction is a vitally important element in the final satisfactory solution of providing a proper environment for producing animals.

2. There is a point in design for heat conservation that must be reached before satisfaction as measured by moisture control can be obtained; that short of this point success is impossible but that beyond it and only a very small way beyond it opportunity for control is practically unlimited.

3. This point in design cannot be precisely known until further research on animal heat and moisture production under varying environmental conditions of temperature and relative humidity is carried through. The authors wish at this time to urge this as a very important project for consideration by public research agencies.

4. We feel that the equipment we have designed and the methods we have devised are sufficiently flexible to be readily adaptable under any variations in conditions that may come about through future research, and that, therefore, in the face of urgent demand from the public we serve we are justified in placing it on the market even in the face of what may appear to be limited experimentally confirmed basic knowledge.

You will be interested to know that at least three college agricultural engineering departments are preparing for research along these lines this coming winter.

(Right) A gully which had its beginning in a wagon track. (Extreme Right) Damage done by erosion is not ended when the fertile top soil of upland fields is washed away. This view shows a Kansas river-bottom orchard which was on the receiving end of a soil movement. The deposit of five feet of erosion debris will destroy or seriously damage this orchard for productive purposes

# Erosion Control on the Federal Projects[1]

By C. E. Ramser[2]

WORK on the research program relating to soil erosion and moisture conservation of the U. S. Department of Agriculture has been in progress since the first part of January 1929. Three experimental farms have been established where both farm operations and experimental work are in progress, and two other farms have been located.

One of the three farms that have been established is located in the red lands region of Oklahoma and Texas, near Guthrie, Oklahoma, another in the black lands of central Texas, near Temple, Texas, and the third in the dark prairie lands of west central Kansas, near Hays, Kansas. One of the two other experimental farms that have been located is in the grey lands of northern Missouri and southern Iowa, near Bethany, Missouri, and the other on the light-colored sandy lands of southwest Arkansas, northeastern Louisiana and east central Texas, near Tyler, Texas. A topographic survey has been completed on the farm near Tyler, Texas, and the preparation of the map is now in progress. It is planned to start a topographic survey of the Bethany farm shortly after the first of the coming year.

Operations were begun on the Guthrie farm in January 1929. The investigations on this farm are being conducted in cooperation with the Guthrie Chamber of Commerce and the Oklahoma A. & M. College. Since the inception of this work about 20 acres of land have been cleared; about 95 acres of land have been terraced on which about 8½ miles of terraces have been constructed; 1800 feet of gullies have been filled with brush; and 45 brush dams, 8 rock dams, 4 woven-wire dams, and 6 pole dams have been built. About 60 acres of the land was planted to cotton and about 40 acres of the badly eroded and gullied land was planted to various cover and green manure crops the first year.

This farm was settled under the Oklahoma homestead act of 1889. About 8 acres of the land was cleared and placed in cultivation between the years 1889 and 1906. Now this area which has been under cultivation is badly gullied, part of which was allowed to lie idle last year on account of its badly eroded and infertile condition. A soil survey shows that 3 to 24 inches of soil has been eroded from the area under cultivation as compared with practically none on the virgin area, and the numerous gullies range in depth from 2 to 10 feet. The bottoms of all of the deeper gullies are down to bed rock. The surface soil on the farm varies from a fine sandy loam to a loam, and in eroded spots it is a clay loam.

The map (Fig. 1) shows the location of the various experiments being conducted on this farm. Five sets of terracing experiments marked 1, 3, 4, 5 and 7 are shown on this map. The set marked 1 consists of six terraces 700 feet in length with vertical spacings of 2, 3½ and 5 feet, on an average land slope of from 5 to 7 per cent and with a uniform fall or grade of 4 inches per 100 feet. The set marked 3 consists of ten level terraces varying in length from 200 to 700 feet and with vertical intervals of 2, 2½, 3, 3½ and 4 feet. The average slope of this field is about 4½ per cent. The north end of these terraces is closed and a small embankment is built 100 feet from this end so that all of the rain that falls on this 100-foot length is retained. The three terraces marked 4 on the map are level terraces. Two of these terraces encircle the top of a knoll near the center of the farm and have no outlet. The ends of the third level terrace are closed. The slope of the land is about 2½ per cent. The experiment marked 5 consists of 4 terraces 1500 feet in length with grades as follows: Level, 2, 4 and 6 inches per 100 feet. The terraces have an average vertical spacing of about 3½ feet, and the average slope of the land is about 4.6 per cent. The terracing experiment marked 7 consists of five long terraces each about ½ mile long. Two of these terraces which are on virgin soil have variable grades. The grades increase from level to 4 inches per 100 feet for one and from level to 6 inches for the other. Three of the terraces are on soil that has been cultivated for a long time and has been badly eroded. The grades of one of these terraces varies from level to 4 inches per

[1]Paper presented at a meeting of the Land Reclamation Division, of the American Society of Agricultural Engineers, at Kansas City, Mo., December 1929.

[2]Senior drainage engineer, division of agricultural engineering, Bureau of Public Roads, U. S. Department of Agriculture. Mem. A.S.A.E.

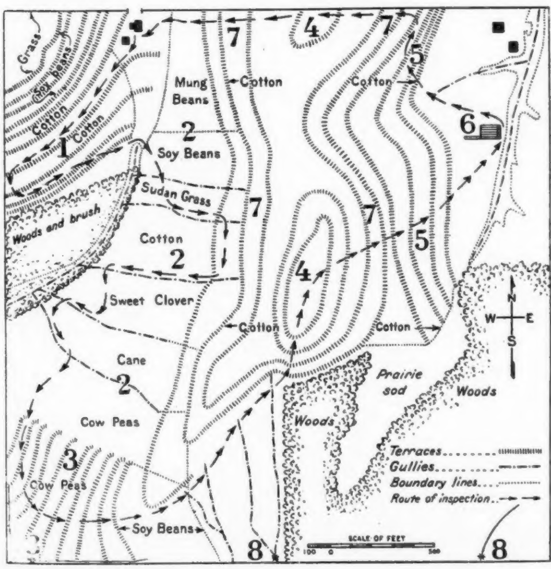


Fig. 1. Guide map of Guthrie, Oklahoma, Soil Erosion Experiment Farm, prepared July 1929. References: (1) Six graded terraces 700 feet long with 2, 3½ and 5-foot vertical intervals and a fall of 4 inches per 100 feet; (2) seven plots in different cover crops and one cotton check plot, all in cotton alternate years; (3) ten level terraces with vertical intervals of 2 to 4 feet, 100-foot closed strip at north ends, open south ends; (4) three level terraces built with no outlets so that all water is retained; (5) four terraces 1500 feet long, one level and others with uniform grades of 2, 4 and 6 inches per 100 feet; (6) nine plots in different crops, from which the runoff and erosion are measured in concrete tanks; (7) five graded terraces about one-half mile long, one on eroded land with a uniform fall of 3 inches per 100 feet and two each on eroded and virgin land with variable falls of level to 4 inches per 100 feet and level to 6 inches per 100 feet; (8) location of runoff gaging stations on terraced, unterraced and wooded watersheds

100 feet, for another from level to 6 inches per 100 feet, and the third terrace has a uniform grade of 3 inches per 100 feet. The average slope of the land is about 3.6 per cent.

The experiment indicated on the map as 2 consists of a series of plots on a badly eroded and gullied slope. The plots were planted to various cover crops in the late spring of 1929 which were plowed under for green manure in the fall. As indicated on the map these crops were mung beans, soybeans, Sudan grass, sweet clover, cane and cowpeas. These plots will be planted to cotton alternate years and the one plot planted to cotton this year will be continued in cotton every year as a check plot thus affording information on the relative value of the various cover crops as soil builders, and on the rapidity that the soil is built up by comparing yields on the cover crop plots with the yield from the check plot planted to cotton every year. The boundary lines between most of the plots are deep gullies. Soil saving and check dams were constructed in these gullies and in the ravine into which the water from these gullies is discharged.

The figure 6 on the map indicates the location of small plots on a slope of about 7.5 per cent where the run-off and soil losses are measured in concrete bins at the lower end of the plots. These experiments are being conducted by the Bureau of Chemistry and Soils of the U. S. Department of Agriculture and are similar to the experiments which have been carried on at Columbia, Missouri; Raleigh, North Carolina, and Spur, Texas, and will afford information for a different kind of soil and land slope.

The average annual rainfall at Guthrie is about 30 inches. Two self-recording rain gages have been installed on the Guthrie farm. One is a weighing and recording rain gage which keeps a continuous record of the rain on a chart fastened to a revolving vertical cylinder. The amount of rainfall can be estimated to the nearest 0.01 inch on this chart and the time to about the nearest two minutes. The other is a tipping bucket rain gage which records the rainfall in hundredths of an inch; the capacity of the tipping bucket and the time on the chart can be estimated to the nearest minute.

Measurements of run-off and soil losses will be made at the ends of the graded terraces included in the experiments that have been mentioned. The run-off or discharge from the terraces will be measured by means of the improved venturi flume designed by R. L. Parshall, irrigation engineer of the U.S.D.A. Division of Agricultural Engineering. A view of one of these flumes is shown in Fig. 2. This measuring device was selected since experiments show that the discharge will not be appreciably affected by the velocity of the water entering from the terrace channel, and the discharge through the flume for any particular stage is not appreciably affected within certain wide limits by the stage of the water in the channel into which the flume discharges. Such a device eliminates the necessity of storing any of the water to reduce the velocity of approach before the discharge is measured and the necessity of providing a deep outlet channel to preclude the possibility of backwater affecting the rating of the measuring device. Another important reason for choosing this device is that its design is such as to reduce the possibility of silting to a minimum. The increase in the velocity in the contracted section (Fig. 2) near the middle of the flume tends to carry away any silt or drift which has been transported to this section by the slower moving water in the terrace channel and in the upper part of the flume.

Carefully conducted experiments have been made to determine the discharge through these flumes for any stage of water in the upper section of the flume. A continuous record of the stage of water is obtained by an automatic recording float gage located at the side of the upper section of the flume (Fig. 3). The float well shown in the view is connected with the flume by a small hole at the bottom of the flume. The movement of the float in the vertical well box is actuated by the fluctuation of the water level in the flume and by a simple mechanism is recorded on a circular chart. This circular chart is revolved by a clock making one revolution in 12 hours. On this chart a continuous line is recorded showing the stage of water in the flume at any time during the period of flow through the flume. Specifications were prepared relating to the water stage and time scale of this instrument so that the water stage could be read to the nearest 0.01 foot and the time scale to the nearest minute. With these scales the time required for the water to reach the crest stage can be accurately determined and the total discharge through the flume for any particular rain can be computed from which the percentage of rainfall that runs off can be determined quite accurately. In Fig. 4 are shown six flumes with recording gage houses installed at the ends of terraces in the experiment to determine the spacing for graded terraces. No rains causing appreciable run-off have occurred since these flumes were installed in the early summer of 1929.

Experiments are being conducted to devise a satisfactory silt sampler for taking a small portion of the flume discharge from which can be ascertained the amount of silt or soil that is being carried off in the run-off water. A view of a trial silt sampler is shown in Fig. 5. This consists of a box 5 feet wide and 10 feet long installed below the lower end of a flume having a one-foot throat. The bottom of this box is 2 feet below the bottom of the flume and the outlet end of the box acts as a rectangular weir, the crest of which is 2 inches below the bottom of the end of the Venturi flume. The purpose of this box or basin is to trap all the heavier material in the run-off water in that part of the basin below the crest of the outlet weir. The amount of this material can be directly measured, but in order to determine the amount of the silt escaping over the weir at the outlet end of the box it is necessary to obtain a proportionate amount of the weir discharge for all stages of flow. Since it is thought to be impracticable to take a sample of the water by means of a trap perpendicular to the direction of the current of flow on account of drift and debris clogging up the opening into the trap, the sample is taken by means of a trap in the side of the box a short distance above the weir which consists of a vertical notch ½ inch wide, the bottom of which is at the same elevation as the crest of the weir. By this arrangement the water starts flowing over the weir and through the notch at the same time, and as the stage of water rises the head of water on the bottom of both notch and weir remains the same and the cross-sectional area of the flow over the weir and through the notch remains proportionately the same so that a proportionate amount of the water discharged from the flume for all stages flows through the notch. Since the quantity of water trapped by this notch for rains of high intensity will be more than can be stored in a tank of moderate size, the water flowing through the notch is further divided by means of a divisor box which is shown in the figure between the basin box and the circular storage tank. This divisor box which is about 20 inches long, 10 inches wide and 12 inches high, has two notches or weirs in the end of the box. The width of the weirs are ½ inch and 3 inches. The flow from the ½-inch weir enters the storage tank and the flow through the 3-inch weir is wasted. A proportionate amount of the water flowing through the divisor box is in this manner extracted and retained in the storage tank. The silt content of the water in the storage tank and the amount of silt that is trapped in the basin is determined, and with this information and the quantity of water discharged by the flume the total quantity of silt in the total water discharged for each rain can be readily computed. Whether or not this silt sampling device will prove satisfactory depends upon whether a fairly constant proportion of the water is extracted from the discharge through the main basin box for all stages of flow. It is believed, however, that such a constant relation can be obtained by changing some of the dimensions employed in the general design of the apparatus if it is found to be necessary.

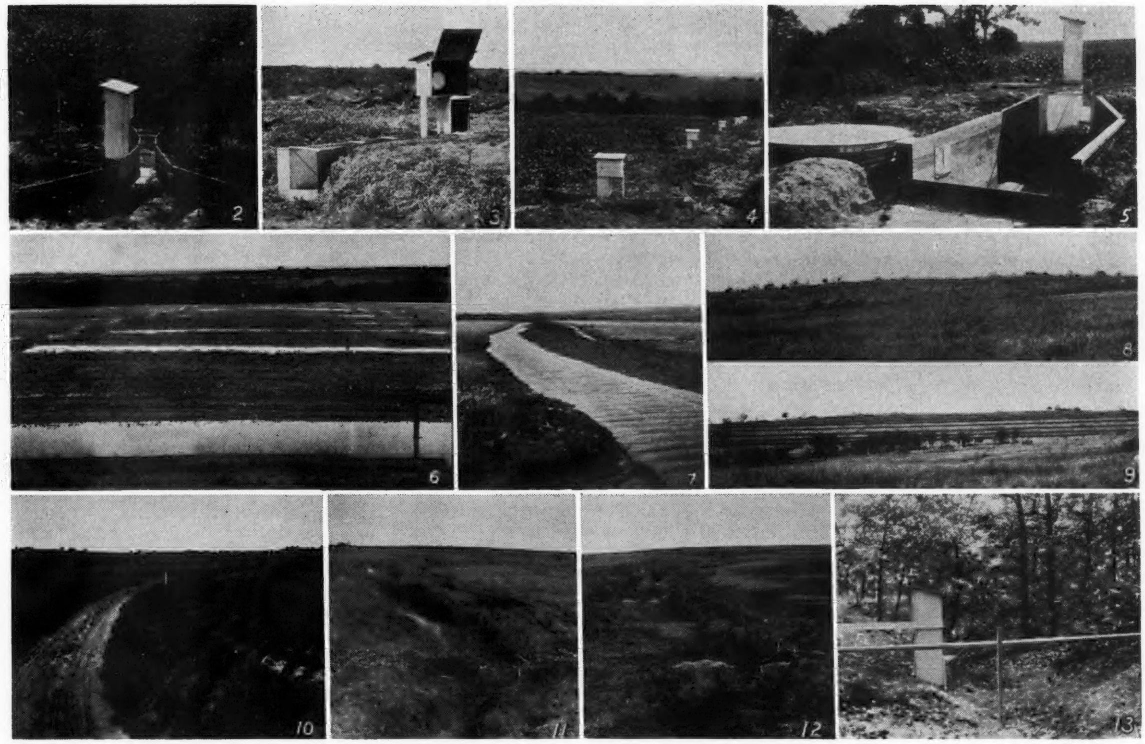


Fig. 2. Venturi flume and water level recorder house installed to measure runoff from terrace channel. Fig. 3. Water level recorder house and well installed with Venturi flume. Fig. 4. Six water level recorder houses installed at ends of terraces in one field. Fig. 5. Trial silt sampler for use in determining the amount of silt in runoff water. Fig. 6. Water impounded along the closed 100-foot length of the level terraces in Field 3, Fig. 1. Fig. 7. Water impounded after a heavy rain by the circular level terrace. Fig. 8. A field covered with a growth of scrub oak and sprouts before terracing work was begun. Fig. 9. Same field as Fig. 8, after terracing. Fig. 10. Soybeans planted in rows across a terrace. Fig. 11. A gully before the construction of pole dams had been completed. Fig. 12. Same gully after the construction of pole dams. Most of the silt which is level with the crests of the dams was caught during one rain. Fig. 13. The gaging station on the wooded watershed

Since no rains of appreciable intensity have occurred at Guthrie since the installation of this silt sampler and since it is not likely that such rains will occur before the coming spring, a similar sampling apparatus has been installed on the state farm near Raleigh, North Carolina, by F. O. Bartel, associate drainage engineer, U.S.D.A. Division of Agricultural Engineering, where it is expected that sufficient rains will occur this winter to test out the sampler, and it is hoped that the results of the tests will be available in time to make the necessary installations on all of the graded terraces on the Guthrie farm before the spring rains.

Lines have been laid out perpendicular to the contours in several locations on the Guthrie farm to determine the soil movement down the slopes for unterraced land, level-terraced land and graded-terraced land. Permanent concrete posts have been set at the upper and lower ends of these lines. Accurate measurements will be made every year to determine the elevation of points along these lines at intervals of six inches. From these measurements information will be obtained on the soil movement down the slope for both terraced and unterraced land. It is generally known that terracing does not entirely prevent but simply retards the soil movement down the slope. The effectiveness of terracing is measured by the extent to which this soil movement is retarded and a comparison of the profiles taken along these lines on the unterraced and terraced land with different spacings of terraces will afford information on this subject. As stated the measurements along these lines will be made every year. It is not thought however that information obtained from these experiments will be of much value before a period of about 5 years has elapsed and that the longer the experiments are continued the more valuable will be the results obtained.

In the two sets of level terrace experiments on the Guthrie farm it is proposed to obtain information on the proper spacing of level terraces and the effect upon crops of water standing above the terraces after rains for the particular soil and land slope. In one set of experiments the level terraces are spaced 2, 2½, 3 and 4 feet apart in vertical distance on a slope of about 4½ per cent and the rain water is retained by means of embankments on a 100-foot section at the ends of the terraces (Fig. 6). Staff gages installed in the channel above these terraces are read at intervals after rains from which information on the time required for the water to percolate into the ground will be obtained. After the first year the effect of moisture conservation upon crop yields will be made by comparing yields on the terraced and an adjoining unterraced area. Where any injury to crops results from standing water in the terrace channel, an effort will be made to ascertain from a comparison of crop yields on terraced and unterraced land whether or not this loss in yield is greater or less than the increased yield due to moisture conservation above the terraces outside the channel.

Similar measurements and observations are being made on the terraces that encircle the knoll near the center of the farm which is shown in Fig. 1. In Fig. 7 is shown water standing above one of these terraces after a heavy rain. Half of the area above these terraces has been subsoiled to a depth of 14 inches. It was found that the water stood above these terraces several days after a heavy rain with resulting injury to crops in the terrace channel and a

delay in tilling and seeding the land in the spring, and it is desired to determine what effect subsoiling will have upon the rate of percolation of the water into the soil. If subsoiling does not relieve the wet condition, tile drains will be installed above the terraces .

In the graded-terrace experiments the principal information that will be obtained will consist of the proper size for the terrace channel, the proper spacing, the fall and the limiting length of a terrace for the particular vegetative covering, soil and land slope. These factors are all interdependent so that a change in any one affects all the others. For instance, the size of the cross-sectional area of the terrace channel depends upon the length and spacing of the terraces which together are the factors that determine the size of the drainage area and since the amount of run-off increases with the size of the drainage area, the larger the drainage area the larger must be the cross-sectional area of the terrace channel to remove the run-off water, other factors being constant. It also depends upon the fall since, with other factors remaining constant, the larger the cross-sectional area, the smaller may be the fall since the discharge capacity of a terrace channel is governed by both the fall and the cross-sectional area. Upon the nature of the vegetative covering, the kind of soil and the inclination of the land slope depends the percentage of the rainfall that runs off and the greater this percentage the greater will need be the cross-sectional area of the terrace channel, other factors remaining the same. From the foregoing it is apparent that a great variety of factors enter into the design of a terrace. It is the problem of the engineer to adjust the relation of these factors in such a manner as to prevent any appreciable erosion on the land slope between the terraces and in the terrace channel, and at the same time to provide sufficient capacity in the terrace channel to prevent the run-off water from overtopping the terrace with the usual disastrous result to the field and the terraces below. The results of these experiments will provide information required in the determination of the proper relation of the various factors involved for the particular soil and land slopes where the experiments are located.

One outstanding problem in terrace design is the maximum length (other factors being constant) that a graded terrace can be built without undue erosion in the terrace channel. The set of experiments consisting of five terraces each about ½ mile long should afford information on this subject from actual measurements of the silt and run-off and from observations along the terrace channel to detect signs of incipient erosion.

In addition to the information to be obtained in the foregoing experiments considerable data have been collected on the cost of constructing terraces of different dimensions with different terracing implements. A sufficiently detailed study of these data has not been made to warrant its complete publication. The costs of the construction of terraces under normal conditions of soil and operation with tractor power ranged from $20.10 to $45.30 per mile of terrace and from $1.92 to $4.22 per acre. The height of these terraces ranged from 1.1 to 1.6 feet and the base widths from 20 to 25 feet. The vertical spacing of the terraces varies from 2 to 4.6 feet and the land slope from 3 to 4.4 feet per 100 feet. The soil ranges from a badly eroded clay loam soil that has been in cultivation for 40 years to a virgin fine sandy loam.

In Fig. 8 is a view of a field before it was terraced. This field was covered with a growth of scrub oak trees and sprouts which greatly interfered with terracing work. Also many rocks and roots hindered the progress of the work. The slope of this field varies from 5 to 7 per cent and the average vertical distance between terraces is about 3½ feet. The cost of terracing this field with terraces 20 feet wide and 1½ feet high amounted to about $13.00 per acre. In Fig. 9 is a view of this field after it was terraced. In computing these costs on terrace construction, some allowance was made for the depreciation of machinery. These costs may be modified somewhat later when more definite information is obtained on the proper allowance to be made for depreciation.

It was found that several variable factors affect the cost of construction of terraces. Some of the factors are the nature and conditions of the soil, the length of the terrace, the vegetative covering, kind of implements used, the methods employed and the experience, skill, intelligence and vigor in prosecuting the work, of the operator. In some instances constructing a terrace in wet soil might easily double the cost. It requires more time and labor to build a terrace in heavy clay than in a sandy loam soil. A short terrace costs more to build than a long terrace due to the greater percentage of time required in turning equipment at the end of terraces. Vegetative covering such as long grass is most generally a source of great annoyance in terrace building and greatly retards the progress of the work. Roots, rocks, sprouts and stumps add materially to the cost of terrace construction and in many cases would likely make the cost of terracing prohibitive. Generally the amount of terracing work done by a farmer on his own farm is not sufficient to make him proficient in terracing work. Two operators differing in skill, vigor and intelligence may readily cause a variation of 50 per cent in the cost of the construction of terraces even where both are experienced. Also until an operator gains sufficient experience, the cost of constructing terraces is appreciably larger. To these many variable factors and to the fact that very little reliable cost data has been collected may be attributed the great difference of opinion among farmers and engineers with regard to the cost of terracing work.

Some observations were made on the cultivation of terraces. Most of the cotton rows were run parallel to the terraces the first year to give the terrace embankments a chance to settle. Next year the rows will be run across many of the terraces and a comparison will be made of these two methods of cultivation as regards to injury to terrace, ease of cultivation and time employed in cultivation. In Fig. 10 is shown rows of soybeans running across a terrace.

In checking erosion and filling in gullies on the farm an effort was made to employ the simplest and cheapest methods. Practically all material used with the exception of a few spikes and smooth wire was available on the farm. Brush was used in building most of the check dams in the gullies. This brush was obtained from the clearing of land for cultivation. The limbs were trimmed from the trees and the poles obtained were used in building pole dams. The area where most of the brush dams were built was not terraced until fall when there had been sufficient filling of these gullies due entirely to spring and early summer rains to enable crossing them with terracing machinery after the edges had been plowed in.

In Figs. 11 and 12 are shown two views of a gully before and after the construction of pole dams. These dams are 1, 1½ and 2 feet high and spaced so that the crest of one dam is at the level of the foot of the dam above. This gully had a width of 1 to 4 feet on the bottom and 6 to 10 feet at the top and a depth of 2 to 4 feet. The deposit of soil shown in the gully varies from 1 to 2 feet deep and occurred during a period of about one month and as a result of about four rains. The edges of the lower end of this gully have been plowed in and it is now being crossed in plowing the field with a tractor.

Measurements of run-off and possibly soil losses will be made from six small areas on the Guthrie farm, consisting of a level-terraced area and five unterraced areas. The watersheds of the unterraced areas are as follows: timber land, abandoned gullied land, sodded land, a cultivated area with rows across the slope and a cultivated area with rows running up and down the slopes. From the results of these experiments a comparison can be made of the effect of the different treatment and cover upon run-off and soil erosion. Gaging stations and self-

**Soil movement down a slope between terraces can be greatly retarded by methods of cultivation and cropping, but it cannot be entirely prevented where cultivation is practiced. From the fact that soil movement down the slope of a cultivated field cannot be entirely prevented, it is apparent that terracing does not stop this movement but merely retards it. It is however sufficient that terracing retards it, if the rate of retardation is great enough to permit the soil to be built up by geolcgical processes, methods of cropping and possibly the application of fertilizer at a rate sufficient to maintain the soil in its original fertility. For most land however it is believed that the rate of building up the soil in terraced fields under good farming methods will be faster than the tearing down process due to the soil movement down the slope.**

recording gages have been installed on the wooded area, the gullied area and the level terraced area. In Fig. 13 is shown a view of the gaging station in the wooded area. Measurements of the discharge at this station will be made from the footbridge with a current meter for different stages in the channel and a continuous record of the stage in the channel will be obtained by means of a self-recording gage. It is proposed later to install Venturi flumes at these stations so as to obtain an automatic record of the discharge.

Operations were begun on the farm near Temple, Texas, in April 1929. The experimental work on this farm which contains 140 acres is being conducted in cooperation with the Texas Agricultural Experiment Station. The surface soil varies from a dark gray to a black clay. The average annual rainfall at Temple is about 35 inches.

About 55 acres of land have been terraced on the Temple farm on which about 5½ miles of terraces have been built. Three sets of terracing experiments have been laid out. One consists of eight level terraces with vertical spacings of 3, 4 and 5 feet and heights of 15 and 18 inches. These terraces were built with base widths of 20, 25 and 30 feet, and range in length from 300 to 1300 feet. Information on the proper height and vertical spacing for level terraces will be obtained from these experiments.

All of the rain water is retained on a 100-foot length at one end of these terraces by means of earth embankments. As in the case of the Guthrie experiments, the effect of moisture conservation and of the water retained above the terraces upon the crop yields will be determined by comparing yields on the terraced land and on an adjoining unterraced area.

Another set of terracing experiments consists of three graded terraces with a uniform fall of 3 inches per 100 feet, a length of 900 feet and a vertical spacing of 3, 4 and 5 feet on a land slope of about 5.3 per cent. Information on the proper spacing will be obtained for the particular soil and land slopes. A third set of terracing experiments consists of five terraces each about 2,000 feet long. They have grades as follows: uniform, (3, 4 and 5 inches per 100 feet and variable), level to 3 inches, and level to 5 inches. Information will be obtained on the erosion in the terrace channels with different grades and comparisons will be made of the extent of erosion in the channels with uniform and variable grades where the grades are the same at the lower end of the terraces. It is also desired to obtain information on the rate of run-off from variable-graded and uniform-graded terraces for the same intensity of rainfall.

As is generally known the grade of variable-graded terraces increases from the upper to the lower end of the terrace. The grade of a natural stream channel generally decreases from the upper to the lower end since the formation of the watershed is an erosional process which extends upward into the watershed areas. The slopes are therefore naturally steeper in the upper than in the lower reaches of the channel. However, in order to accommodate the increasing amount of water contributed by the increasing size of drainage area, the cross-sectional area of a stream increases as the mouth of the stream is approached. Where there is no appreciable flooding of the lands along the lower reaches of the stream the increase in cross-section is very pronounced. The cross-sectional area of a terrace channel is the same throughout its length from which it follows that with a uniform grade the discharge capacity is the same at the upper end as at the lower end. Since the drainage area of the terrace increases from the upper to the lower end of the terrace, it is apparent that if the lower end of the terrace channel has sufficient capacity to remove the run-off water, the upper end would have an unduly large capacity. In fact, a comparatively small ridge would handle the run-off at the upper end of the terrace, and the terrace embankment in order to handle the run-off satisfactorily would need only increase uniformly from the size of a small ridge with a terrace channel having a small discharge capacity at the upper end to the size of a normal terrace embankment with a channel having a large discharge capacity at the lower end of the terrace. This would necessitate building a terrace embankment of varying size from the upper to the lower end of the terrace. Since this would doubtless be regarded as impracticable by most farmers, it is desirable that the cross-sectional area of the terrace channel remain the same throughout the length of the terrace. Under this condition if the terrace channel at the lower end of the channel for a certain grade has sufficient discharge capacity, then the terrace channel with a similar cross-sectional area at the upper end of the terrace has an excessively large capacity for the same grade. It is therefore possible to start with a small grade at the upper end of the terrace and increase this grade uniformly to the lower end of the terrace in order to remove the water contributed by the increasing size of the watershed area. From this it is apparent that the grade of the variable-graded terrace with a constant cross-sectional area should increase going downstream while the cross-sectional area of a natural stream should increase proceeding downstream, since the grade decreases proceeding downstream.

The water travels faster from the upper to lower end for a uniform-graded terrace than for a variable-graded terrace on account of the greater fall. Suppose for two terraces of the same length—one with a variable and the other with a uniform grade—that it takes 10 minutes for water to travel from the upper to the lower end of the uniform-graded terrace and 15 minutes for a variable-graded terrace. Now suppose an intense rain continues for ten minutes, then the discharge at the lower end of the uniform-graded terrace at the end of ten minutes would be made up of water received from all parts of the drainage area, while for the variable-graded terrace the water from approximately the upper one-third of the drainage area would not have reached the outlet at the end of ten minutes since it requires fifteen minutes for the water to travel the length of the variable-graded terrace channel. Only about two-thirds of the drainage area would be contributing water to the flow at the lower end of the variable-graded terrace at the end of ten minutes when the rain stops. From this it is seen that the discharge produced by rainfall from only two-thirds of the drainage area of the variable-graded terrace would be smaller than from the whole area of the uniform-graded terrace. Now suppose the rain continues for 15 minutes at the same intensity, then the discharge from both terraces would be the same. However, long-time records of the U. S. Weather Bureau show that the heaviest rainfalls lasting ten minutes have a higher intensity than the heaviest rainfalls lasting 15 minutes, from which it is seen that, if the rain under discussion continued for 15 minutes, it would continue at a reduced intensity, and so the discharge from the variable-graded terrace would never equal the discharge from the uniform-graded terrace which occurred at the end of the ten-minute period, when all parts of the drainage area were contributing water at a rate corresponding to the high rainfall intensity. From the foregoing it is apparent that a smaller grade can be used to remove the water with a variable-graded terrace than with a uniform-graded terrace of the same length, or for the same discharge at the outlet a variable-graded terrace can be made longer than a uniform-graded terrace.

The experimental farm near Hays, Kansas, is located on the Fort Hays Agricultural Experiment Station lands and contains an area of about 200 acres. The average annual rainfall in this locality is only about 20 inches so that the problem of conserving the rainfall is important. For this reason terracing experiments to conserve moisture will be emphasized on this farm. About 5 miles of level terraces have been built on the flatter land of this farm which has a fall ranging from 0.2 to 2 per cent. The surface soil varies from a dark brown loam to a clay loam.

Six plots, V, U, T, S, R and Q, make up an experiment on the proper spacing of terraces on flat slopes, on the effect of subsoiling the land above terraces, and on the effect of subsoiling the unterraced land. On Plot Q the terraces are spaced with a vertical interval of six inches. On Plot R the terraces are similarly spaced, but the land is subsoiled. Comparison of the effect of moisture conservation for Plots Q and R will be made to determine the effect of subsoiling. In Plot S the terraces have a vertical interval of 1 foot, and the land is subsoiled for comparison of the effect of moisture conservation with Plot T where the terraces are similarly spaced. Plots Q and R will also be compared with T and S to determine the effect of spacing upon moisture conservation. Comparisons will be made by means of crop yields and moisture determinations from soil samples taken at depths of 4 to 6 feet.

Plots U and V are unterraced areas. Plot U is subsoiled to conserve the moisture for comparison with Plot V which will be farmed in the ordinary manner. Comparison of the conditions as to crops and moisture on Plot V will also be made with the other plots in the experiment. The terraces on the flatter land are built with base widths of 30, 35 and 40 feet and with heights of 9 and 12 inches. Two methods were employed in building the terraces: moving all the dirt from both sides and from the upper side for comparison of the cost of construction of terraces built by these different methods. Observations will be made on crossing terraces with different base widths to determine the most satisfactory base width for the required height in the satisfactory operation of large farm machinery.

On the federal soil erosion projects research work will be conducted relating to all methods of preventing and checking erosion, but special attention will be directed to terracing. Terracing undoubtedly has the widest practical and general application in the cure and prevention of soil erosion. It may be applied to conserve the fertility of virgin soils, to preserve the remaining fertility of depleted soils where erosion has been active, and to restore fertility to gullied and badly eroded lands that have been abandoned for cultivable purposes. Terraces can be designed and constructed so as to save practically all the soil or very little. On the one hand, level terraces with ends closed so as to retain all of the rainfall permits practically none of the soil to escape from the field, while, on the other hand, terraces with a large fall to carry the water off of the field also generally carries away much of the soil that accumulates in the terrace channel. Owing to the fact that the latter method prevents the development of gullies in a field, the farmer is often mistakenly led to believe that he has successfully stopped erosion and its accompanying soil losses. These two extreme methods of terracing also represent two extremes in cost of construction and maintenance per acre of field terraced. The cost of construction of a level-terrace system is larger than a graded-terrace system since level terraces must be placed closer together or built higher in order to store the run-off water which is permitted to drain off in a graded-terrace channel. The cost of maintenance is also larger since there is a certain amount of soil movement down the slope between terraces and the accumulation of this soil in a level-terrace channel is faster than in a graded-terrace channel, for the reason that most of the soil remains in a level-terrace channel and part is removed by the run-off water in a graded-terrace channel. Maintenance work consists partly of cleaning the accumulated soil out of the terrace channel and using it to strengthen the terrace embankment.

Soil movement down a slope between terraces can be greatly retarded by methods of cultivation and cropping, but it cannot be entirely prevented where cultivation is practiced. From the fact that soil movement down the slope of a cultivated field cannot be entirely prevented, it is apparent that terracing does not stop this movement but merely retards it. It is however sufficient that terracing retards it, if the rate of retardation is great enough to permit the soil to be built up by geological processes, methods of cropping and possibly the application of fertilizer at a rate sufficient to maintain the soil in its original fertility. For most land however it is believed that the rate of building up the soil in terraced fields under good farming methods will be faster than the tearing down process due to the soil movement down the slope.

Up to the present time there has been practically no study or consideration given to the economics of terracing. Only a careful study of this subject involving the consideration of the many cost factors and influencing conditions together with the degree of erosion control will enable the engineer to specify with precision the sort of terrace best adapted to any particular piece of land. It is hoped that the results of the experiments on the federal soil erosion projects will afford information of value required in a much needed economic study of the terracing problem. Until such information is available, however, it is important that terracing work be pushed vigorously since the great benefits derived from terracing are so self-evident that the good work should continue unabated regardless of the possible improvements that could be made if adequate experimental data were available for present use.

# Results of Tests of a Continuous Process Feed Grinding Plant[1]

By J. E. Nicholas[2]

ON MAY 1, 1928, the Pennsylvania Agricultural Experiment Station authorized a research project in the department of farm machinery, the object of which was to determine the best application of portable electric motors, maximum capacity of 7½ horsepower, to Pennsylvania agriculture.

A progress report on the use of small electric motors for cutting ensilage, sawing wood, and grinding feed was published in May 1929. H. B. Josephson and R. U. Blasingame outlined in this report the results obtained from tests conducted during the fall and winter of 1928, using 3, 5, and 7½-horsepower, 220-volt, 60-cycle, 1800-r.p.m., single-phase portable motors.

This paper is an additional chapter to this report but deals with a new field—that of grinding feed, elevating, mixing and bagging it in one continuous process.

**The Plant.** The plant is installed on J. J. Markle's dairy farm near State College. It consists of a 5-horsepower, 220-volt, 29.4-ampere, 60-cycle, single-phase, 1800-r.p.m. motor with 5½-inch diameter, 6-inch face paper pulley, driving an 8-inch plate (or burr) mill through a 5-inch 4-ply canvas belt. The distance from center of motor to center of mill is 8 feet 4 inches.

The mill shaft carries three pulleys. Two of these, of 18-inch and 14-inch diameter, are placed adjacent and therefore interchangeable, to obtain two different speeds of mill when desirable. Thus, when the motor belt runs over the 14-inch diameter pulley, the 18-inch pulley is used to drive the mixer. The third pulley on the mill shaft is placed on the opposite side of the hopper. It is 2 inches in diameter with 1½-inch face. This pulley drives the elevator through a 1½-inch, 4-ply canvas belt running over a 30-inch diameter 3¾-inch face pulley which is mounted on the top shaft of the elevator.

A short right-angle boot at the bottom of the elevator contains a short sprocket drag-line. This carries the ground feed, which drops from the auxiliary hopper beneath the mill spout to the bucket compartment, where it is elevated into the mixer by a continuous sprocket chain carrying 22 buckets equally spaced. The short drag-line is, in turn, driven by a sprocket chain near the bottom and outside of the elevator. The speed of the elevator pulley is approximately 60 r.p.m.

The elevator is a box type and is self-sustaining. Fig. 1 indicates the construction. The two narrow sides consist of ¾-inch by 4⅝-inch wood boards and the other two light galvanized sheet iron.

The mixer is a tank 27 inches in diameter built of light sheet metal; the straight portion is 5 feet long and has a tapered bottom 24½ inches long. The bagging attachment is 32 inches from the floor line. A hand slide plate, held by a thumb setscrew, permits the emptying of the mixer when bagging. The mixer tank is supported by three angle iron legs equally spaced.

Through the center of the mixer, running from top to bottom, is an auger type screw 12 inches in diameter which mixes the feed. It is operated through a set of bevel gears from a shaft on top of the mixer. This shaft is driven by a 32-inch diameter 6-inch face pulley through a 6-inch wide 4-ply canvas belt obtaining the power from the mill.

The speed of the mixer screw is approximately 150 r.p.m.

**Method of Testing.** All the material to be ground was weighed on platform scales; allowance was made for weight of bag. Two series of tests were made. In the first series, the mill operated at 700 r.p.m., using the 14-inch diameter pulley to drive the mill and the 18-inch diameter pulley to drive the mixer. In the second series of tests the mill and mixer pulleys were reversed, the mill being driven at 550 r.p.m. Table I gives the speed of various elements under the two given conditions.

The oats were ground first followed by barley and ear corn. In all cases ear corn was used. While grinding grain the mixer belt was removed to reduce power consumption. The other ingredients that constituted the final mix were added when grinding was completed. The ingredients used depended on the mix desired, whether cow or hog. Dairy feed and peanut hulls comprised the cow mix; tankage, manamar, middlings and oil meal formed the hog mix. The grain for hog mix was ground finer than for cow mix.

The maximum capacity to which the mixer could be filled was eight bags or 670 pounds.

**Fineness.** Tables II and III seem to indicate that there is some variation in the kilowatt-hour consumption per

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[1]Paper presented at a meeting of the Rural Electric Division of the American Society of Agricultural Engineers, at Chicago, December 1929. Publication authorized by the director of the Pennsylvania Agricultural Experiment Station as Technical Paper No. 493.

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**TABLE I. Speed in R.P.M. of Various Elements Under Two Conditions**

| Motor | Mill | Mixer | Mixer screw | Elevator |
|---|---|---|---|---|
| 1800 | 700 | 398 | 160 | 61 |
| 1800 | 550 | 240 | 96 | 50 |

**TABLE II. Energy Consumption for Grinding and Mixing**
[With 5-hp. single-phase, 220-volt, 1800-r.p.m. motor and 8-inch plate mill (700 r.p.m.)]

| | Grinding | | | | | | Mixing | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | Material ground | Pounds | Time to grind min. | Kw-hr used | Kw-hr. per 100-lb. | Fineness modulus | Pounds ground | Total mix, lb. | Mix and bag Time, min. | Mix and bag Kw-hr. | Total kw-hr. |
| 1 | Barley | 124 | 18 | 1.3 | 1.05 | 3.22 | | | | | |
| | Ear corn | 160 | 22 | 2.1 | 1.31 | 2.81 | 380 | 680 | 8 | 0.5 | 5.3 |
| | Oats | 96 | 18 | 1.4 | 1.46 | 2.93 | | | | | |
| 2 | Oats | 248 | 53 | 4.3 | 1.74 | 2.78 | 248 | 530 | 8 | 0.5 | 4.8 |
| 3 | Oats | 280 | 63 | 5.5 | 1.96 | 2.82 | 280 | 630 | 8 | 0.6 | 6.1 |

**TABLE III. Energy Consumption for Grinding and Mixing**
**[With 5-hp., single-phase, 220-volt, 1800-r.p.m. motor and 8-inch plate mill (550 r.p.m.)]**

| Grinding | | | | | | | Mixing | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Mix and bag | | |
| Test | Material ground | Pounds | Time to grind, min. | Kw-hr. used | Kw-hr. per 100 lb. | Fineness modulus | Pounds ground | Total mix, lb. | Time, min. | Kw-hr. | Total Kw-hr. |
| | Barley | 84 | 13 | 0.80 | 1.05 | 3.21 | | | | | |
| 4 | Ear corn | 150 | 23 | 1.70 | 1.13 | 2.80 | 330 | 630 | 8 | 0.50 | 4.00 |
| | Oats | 96 | 15 | 1.00 | 1.04 | 3.11 | | | | | |
| | Barley | 82 | 13 | 1.00 | 1.22 | 3.22 | | | | | |
| 5 | Ear corn | 156 | 25 | 1.70 | 1.09 | 2.69 | 334 | 634 | 8 | 0.50 | 4.65 |
| | Oats | 96 | 22 | 1.45 | 1.51 | 2.86 | | | | | |
| | Barley | 90 | 13 | 0.90 | 1.00 | 3.12 | | | | | |
| 6 | Ear corn | 170 | 26 | 2.00 | 1.18 | 2.75 | 356 | 656 | 8 | 0.50 | 4.60 |
| | Oats | 96 | 15 | 1.20 | 1.25 | 2.89 | | | | | |
| | Barley | 76 | 13 | 1.00 | 1.32 | 3.11 | | | | | |
| 7 | Oats | 165 | 40 | 3.10 | 1.88 | 2.76 | 361 | 496 | 6 | 0.30 | 5.50 |
| | Wheat | 120 | 15 | 1.10 | 0.92 | 2.61 | | | | | |
| | Barley | 102 | 14 | 1.18 | 1.16 | 2.95 | | | | | |
| 8 | Ear corn | 150 | 20 | 1.83 | 1.22 | 2.71 | 338 | 652 | 8 | 0.50 | 5.28 |
| | Oats | 86 | 22 | 1.77 | 2.06 | 2.59 | | | | | |
| | Barley | 77.5 | 8 | 0.65 | 0.84 | 3.22 | | | | | |
| 9 | Ear corn | 174.0 | 22 | 1.86 | 1.07 | 2.94 | 339.5 | 638 | 8 | 0.45 | 4.13 |
| | Oats | 88 | 16 | 1.17 | 1.33 | 2.97 | | | | | |

100 pounds of grain ground. The actual comparison lies in the "fineness",[3] which was determined by the standards adopted by the American Society of Agricultural Engineers.

The curves of Fig. 2 show the comparison of fineness as plotted against kilowatt-hours per 100 pounds of oats, barley, and corn.

Tables II and III show the results of the two series of tests when the mill is operated at 700 and 550 r.p.m., respectively.

Table IV shows the results obtained by Mr. Markle on his own initiative.

**Power Empty.** Any machine will consume power when running idle. To determine the power consumed, tests were made in various combinations. The mixer and elevator belts were dismantled, and the empty mill was allowed to run for ten minutes while a rapid watt-hour meter was used to record the power consumed. The belt was put on the mixer to obtain the power consumed by the mill-mixer combination. Table V shows the results of all combinations while running empty.

Table VI indicates the time and power necessary to obtain a ton of mix based on these tests.

[3]Progress report on the use of small electric motors, Pennsylvania State College Agricultural Experiment Station, State College, Pennsylvania. Also C. R. E. A. Bulletin Vol. IV. No. 1, published by the Committee on the Relation of Electricity to Agriculture, 1120 Garland Building, Chicago, Illinois.

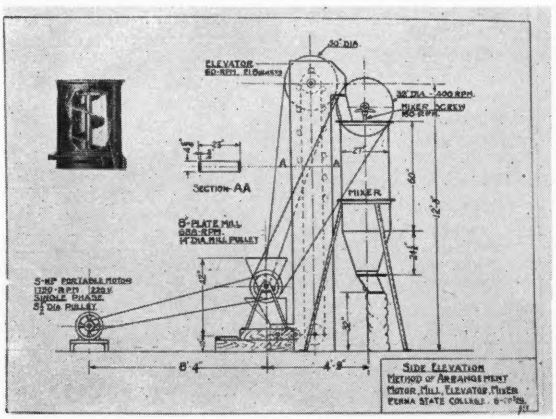
**TABLE V. Energy Consumed by Various Combinations when Running Empty**

| Unit | Kilowatts |
|---|---|
| Mill | 0.87 |
| Mill and elevator | 1.11 |
| Mill and mixer | 1.20 |
| Mill, mixer and elevator | 1.51 |

**TABLE IV. Energy Consumption for Grinding and Mixing**

| Grinding | | | Kilowatt-hours | | |
|---|---|---|---|---|---|
| Material | Weight, pounds | Total weight of mix pounds | To grind | To mix | Total |
| Barley | 100 | | | | |
| Ear corn | 140 | 590 | 3.2 | 0.7 | 3.9 |
| Wheat | 130 | | | | |
| Oats | 140 | 560 | 2.7 | 0.5 | 3.2 |
| Barley | 70 | | | | |
| Ear corn | 140 | | | | |
| Oats | 70 | 610 | 3.6 | 0.4 | 4.0 |
| Wheat | 120 | | | | |
| Oats | 140 | 560 | 4.6 | 0.6 | 5.2 |

NOTE: These data were obtained by Mr. J. J. Markle and no attempt was made to record the fineness or the time required for the operations. The speed of the mill during these tests was 550 r.p.m.



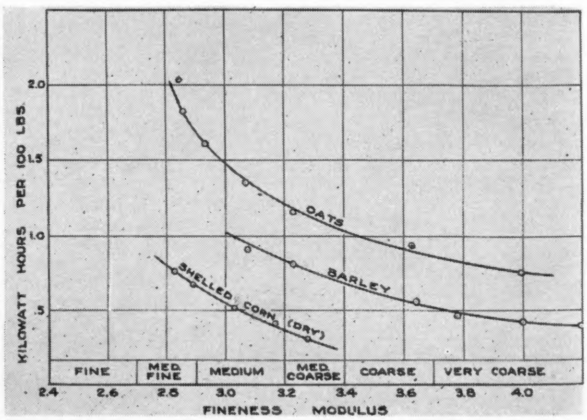




Fig. 1. (left) Side elevation of arrangement of motor, mill, mixer and elevator. Fig. 2. (right) These curves show the relation between fineness modulus and kilowatt-hours per 100 pounds of grain ground

RESULTS

In the progress of this experiment it became evident that the ingredients are satisfactorily mixed at the end of four minutes with an approximate energy consumption of ¼ kilowatt-hour.

Fineness modulus expresses numerically the fineness of the material ground. Finely ground material has a low fineness modulus, and, conversely, a high fineness modulus indicates coarse grinding. It takes more power and a longer period of time to grind the same kind of material to a low fineness modulus than a high fineness. For example, in Test 4 grinding 96 pounds of oats with a fineness modulus of 3.11 required only 15 minutes and an energy consumption of 1 kilowatt-hour. In Test 8, it required 22 minutes and 1.77 kilowatt-hours to grind 86 pounds of oats with a fineness modulus of 2.59. A fineness modulus of 3.11 and 2.59 would be classified in the fineness of grinding as "medium" and "fine," respectively.

Bagging is the final operation. Bags can be filled much faster when the mixer screw is in operation, as this stirs the feed and it falls in a continuous stream to the bag. With the mixer screw idle, the feed has a tendency to hang up and it becomes necessary to tap the mixer.

To prepare feed with the combination grinding, elevating and mixing equipment described in this paper requires the attention of only one operator.

**TABLE VI. Time and Energy Per Ton of Mix**

| Test No. | Kilowatt-hours used (Based on ton of mix) | | Time in hrs. to grind, mix and bag (Based on ton of mix) |
|---|---|---|---|
| 1 | 15.6 | 700 R.P.M. 17.66 average | 3.13 |
| 2 | 18.1 | | 3.84* |
| 3 | 19.3 | | 3.65* |
| 4 | 12.7 | 500 R.P.M. 15.45 average | 3.12 |
| 5 | 14.7 | | 3.57 |
| 6 | 14.0 | | 3.16 |
| 7 | 22.22 | | 4.84* |
| 8 | 16.2 | | 3.26 |
| 9 | 12.9 | | 2.82** |

*Hog feed.

**All material ground coarser.

NOTE: During Tests 1 to 3 the speed of the mill was 700 r.p.m., and during Tests 4 to 9, 500 r.p.m. In the first three tests the average energy used was 17.66 kw-hr., and in the last six tests, 15.45 kw-hr.

# What Electric Utilities Can Do for Agriculture[1]

## By H. C. Fuller[2]

THE introduction of a report read at the convention of the National Electric Light Association in 1913, in discussing electricity in rural districts, states two opinions:

1. The income from farm business alone as developed in the central states at present does not, as a rule, justify the expense necessary in securing the business

2. Some reasons other than the farm business must, for the present, be found for extending lines across the country and the farm business picked up as a by-product.

Twenty-three pages of the report are devoted to electricity on the farm and the remaining ninety-nine are devoted to the development of rural industries of various kinds, together with methods of distribution to this type of customer. It is clear that farm business was purely incidental. After looking at some of the farms which were electrified in those days, especially the wiring, I wonder that the power companies even thought they were incidental and worth running a service to. There certainly was nothing attractive about the farm as a customer.

If developments in the use of electricity on the farm and in the farm home had not occurred, I do not think that we would be much farther along in rural electrification now than we were in 1913. However, a change has occurred. Utility executives, college professors and agricultural leaders with vision had faith that at least a portion of the power requirements on the farm could be met with electricity and that the farm home was just as desirous of the advantages that electricity can bring as any other home, and that the whole problem could be solved.

Reports on individual applications of electricity in agriculture will show that some tangible results have already been accomplished. We have already seen rural business grow to such proportions that it is no longer considered by most companies to be incidental, and we will agree that any company which neglects its rural business is neglecting a real opportunity.

Electricity is no longer considered by agriculture as a luxury. It is rapidly becoming a necessity on the farm, as it is now in industrial plants. It is recognized as a ready and willing servant which can greatly increase the efficiency of farming operations. How much of the burden of work on the farm can be done with electricity will very largely determine how far and how rapidly central station electric service will be extended in rural sections. There is nothing new in the idea that the use made of the service determines how much the power company is justified in expending to connect the consumers. The following figures will show that some success has been obtained.

It is estimated by the Committee on the Relation of Electricity to Agriculture that there are at present 500,000 electrified farms in the United States, and that at the rate at which extensions are being made there will be 1,000,000 electrified farms within the next five or six years. This is a business of considerable magnitude. If 500,000 farms are to be electrified within the next few years, we will have to build approximately 125,000 miles of distribution lines. If the complete cost of these lines averages $2,000 per mile, we will spend $250,000,000, of which some two-thirds will be for material.

It is estimated that the electrified farms of today, on an average, have spent about $720 for electrical equipment. If this be true, it would be fair to assume that those of the next few years will spend on an average of at least $750. Multiplying this by the half-million farms means a total expenditure of $375,000,000 for electrical merchandise. If new equipment can be developed which is of real value, this figure will be greatly increased. It would seem that figures of this sort would convince anyone responsible for the promotion of the electrical industry that the business is of sufficient magnitude to justify the expenditure of a reasonable amount in order to study the economics of the situation and to secure solutions of the many problems involved.

If the solution really lies in the actual direct use on the farm, it is fair to draw some conclusions from an experience had in solving an individual problem on a farm. I am going to tell you a story of one which I think is

[1]Paper presented at a meeting of the North Atlantic Section of the American Society of Agricultural Engineers, at Amherst, Mass., October, 1929.

[2]Rural service division, Utica Gas and Electric Co. Jun. Mem. A.S.A.E.

A farmstead which has been using electricity for 18 year and which consumes about 12,000 kilowatt-hours per year

typical and which has undoubtedly been experienced by many rural service men.

I was recently called to a small farm in central New York to assist the farmer in applying an electric motor to his silo-filling outfit. The farm was of average size in this section and is operated by two brothers who are young and ambitious and who like farming. Like most farmers in this section, they are not blessed with very much money. They had an ensilage cutter which had been on the farm for about five years, and one 35-foot and one 45-foot silo. I found them ready and willing to do everything possible to do this job electrically.

The cutter was standing outdoors and in very bad condition. I found that it had been delivered to the farmer from a freight car; that it had never been adjusted by anyone familiar with this type of equipment; and that the farmer had never had any instruction in its proper care and use. It was in a sad condition. The shear plate was broken, the knives were improperly adjusted, the thrust bearing was entirely out of adjustment and the clearance between the paddle wheels and the case was no where near correct. It was necessary to spend an entire day in overhauling the machine and in teaching the farmer how to properly care for it. I also found that no accurate information was available as to the most economical speed to operate the cutter when used with a 5-hp. motor. It was necessary to experiment with different speeds to determine this. I also found that the shaft on the cutter was not of a size which will permit the use of standard size pulleys, such as are supplied by mill machine houses. We were finally able to blow corn into the 35-foot silo by splitting the bundles and being very careful not to overload the machine.

Unfortunately I had to leave the farm before a complete solution had been reached, but I pointed out to the farmer a number of additional refinements which might improve the operation. I was away from the farm for about ten days. When I next visited the farm, I found the farmer successfully putting whole bundles into the 45-foot silo, and he was immensely pleased with his success. With some assistance from the rural service man, he had practically solved the problem himself, the solution being dependent upon four things:

1. Overhauling and maintaining equipment in first-class operating condition
2. Careful judgment in the application of electric drive
3. Education of the farmer in the care and use of the equipment
4. Some changes in the general farming practice to meet the new conditions.

It seems to me that the final solution, in most of the problems of this kind, will depend upon the following conditions:

1. The utilities must employ men who are especially trained and responsible for this work. They must have a thorough knowledge of farm problems, and must also be familiar with the possibilities of electrical equipment. They must have the ability to see the problem at hand and to educate the consumer as to its proper solution. Furthermore, they must be thoroughly in sympathy with the farmer and must have a sincere desire to assist him in making use of this new force.

2. I believe that we have been inclined to question whether or not we can drive a certain machine with electricity, whereas we should consider whether we can design a machine which will do the job and which can be driven electrically. It appears that a further standardization of drives, shafts, pulleys and belt speeds would be of great value. It is entirely possible that complete systems of agricultural equipment will be developed so that a number of machines will be interchangeable with a single power unit.

3. The development of electrically driven machinery along lines which are economically sound offers an ever increasing opportunity for the manufacturer and distributor.

4. The agencies which are responsible for the education of rural people have a great opportunity to assist the farmer by teaching him how to properly care for the new machinery which comes with electricity, and also to assist him in adjusting his farming practices to the new conditions.

5. I can never lose sight of the human side of the problem. After all, the most important benefit which can be derived from rural electrification is the improvement of the man who spends his lifetime in agricultural pursuits. I would like to quote a sentence from a recent interview with a man who has a reputation for making dreams come true. Henry Ford says: "Having the energy of electricity to do our bidding, there is no reason for human backs to strain, for arms to lift, or legs to stagger under heavy loads." To do this lifting and carrying for American farmers is the task set for the electrical industry. With the assistance of agriculture itself it can and will be accomplished.

# Research in Land Reclamation, 1928

By R. W. Trullinger[2]

RESEARCH in land reclamation seems to have received considerable impetus during the year, especially in some of its more fundamental aspects. It is interesting to note that there were 16 Purnell and 7 Adams fund projects active at the agricultural experiment stations during the year, which dealt with land reclamation problems. These included studies of ground water movement, soil moisture evaporation, duty of water, water absorption, runoff, percolation, soil erosion, drainage reclamation, fundamental soil moisture constants, conditions governing the application of irrigation water, terraces, surface water supplies, ground water supplies, irrigation and drainage pumping, and irrigation and drainage structures.

No record is available as to the total number of land reclamation projects active at the agricultural experiment stations during the year. During the previous year, however, the total number was seventy-nine. The results of official visits to the stations indicate that, while the total number of projects in reclamation may not have actually increased, there was considerable improvement in some quarters resulting from revision of old projects or substitutions of new ones,

While very few results were reported during the year, owing apparently to the comparatively recent development of fundamental conceptions of land reclamation problems, attention will be drawn in the following to a few outstanding progress results to indicate the general trend of the work.

## IRRIGATION

The cost of irrigation practices is assuming a position of considerable importance in the total cost of agricultural production in arid and semi-arid regions, and, in some cases, in the humid regions where supplementary irrigation is practiced. The necessity for maximum economy and effectiveness in irrigation methods and structures is therefore pressing.

It appears that the proper use of irrigation water is influenced to a considerable extent by the requirements of individual crops and the factors governing its retention and movement in specific soils. The Washington Agricultural Experiment Station, for example, found in experiments with corn that the yields are not greatly influenced by different irrigation treatments so long as the soil moisture content is kept reasonably above the wilting point and below the saturation point. With alfalfa no special advantage was secured by applying water more often than every 30 days at rates of as much as 7 acre-inches per acre, whereas irrigation at 6 weeks intervals ordinarily resulted in reduced yields even with comparatively heavy applications.

The California Agricultural Experiment Station found that differences in soil moisture above the wilting coefficient, even if caused by irrigation within a few days of picking, did not produce differences in the canning quality of peaches. A remarkable constancy was shown in the residual moisture content of any given soil at the beginning of wilting of plants even under widely varying evaporating conditions. The results showed, however, that while the residual moisture of some soils at wilting closely agrees with the 1.84 ratio of Briggs and Shantz, the general use of this ratio is open to criticism. The experimental plants were able to reduce the moisture of different soils to different points prior to permanent wilting, the ratios between the moisture equivalent and the wilting coefficient ranging from 1.73 to 3.82.

The California station also found that of the water applied to rice fields approximately 15 per cent is lost by evaporation from the water surface, 25 per cent by seepage, and 60 per cent by transpiration. In fact the conclusion was drawn that under average irrigation practice in northern San Diego County 60 to 65 per cent of the water applied to an irrigated area serves a useful purpose, and the remaining 35 to 40 per cent is lost by runoff, evaporation, and deep penetration.

The U. S. Department of Agriculture found that when sandy loam soil having a moisture equivalent of about 16 per cent was irrigated it held about 16 inches of water in the first 6 feet. When the available supply of water was absorbed by a crop of alfalfa it still contained about 5 inches of water in the first 6 feet. The conclusion was drawn that with this soil the proportion of water available to crop plants is about 70 per cent of the field-carrying capacity. The indications were that, when the soil contains less water than its field-carrying capacity, the loss of water by vaporization takes place not only at the soil surface but also well down into the soil. Under the same conditions it seems probable also that the movement of water through soil toward the establishment of conditions of moisture equilibrium takes place not so much by capillarity as by vaporization and subsequent condensation.

The Idaho Agricultural Experiment Station showed that the rate of infiltration of irrigation water into silt loam soil decreases with the volume weight of the soil. Apparently the effect of porosity on the rate of infiltration is very great. The University of Breslau in Germany found that the air content of soil retards the velocity of irrigation water movement to a considerable extent. The Colorado Agricultural Experiment Station found that the cooling effect of rain on the soil increases the surface tension of the capillary moisture drawn up from the water table and also dilutes the soil solution, so that although adding moisture to the soil at the time, light showers may later cause a more rapid depletion of the moisture already within the soil.

## WATER SUPPLY

The securing of adequate water supplies to meet the requirements of irrigated agriculture is getting to be a problem of serious proportions. The rapid settlement of certain localities is a cause for considerable concern since studies of the available water supplies from surrounding watersheds indicate that the water is used more rapidly than the watershed can supply it. Close cooperation between the agricultural engineers, geologists, and cropping specialists is of considerable importance in such cases in order to make an efficient use of the available water supplies and prevent unnecessary waste.

The Utah and Nevada stations have been especially active in this connection, the former securing evidence of the necessity for reduced annual pumping in certain counties of Utah. Pressure gage readings in the Escalante Valley showed, for example, that the recharge of the underground water supply is sufficient to irrigate only 25 per cent of the total economically irrigable area. Apparently water falling as rain between May and October does not contribute to the underground water supply. The latter station has engaged in a study of the general principles governing the development of underground water supplies from surrounding watersheds as a basis for the development of practices in irrigated agriculture in certain arid localities.

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[1]Paper presented at the 23rd annual meeting of the American Society of Agricultural Engineers, Dallas, Texas, June, 1929.

[2]Assistant in experiment station administration (senior agricultural engineer), Office of Experiment Stations, U. S. Department of Agriculture. Mem. A.S.A.E.

The Utah station has also been engaged in a study of the relation of stream discharge to precipitation which is yielding some interesting results. It appears that snow cover outweighs all other factors in its effect on stream runoff. During the year it was found that the density of snow increases up to a maximum when melting begins and decreases after melting begins. There is a very definite lag in time from when snow starts to melt and water appears as runoff, which is dependent upon temperature and soil moisture conditions when melting begins. It appears that sufficient snow water must go into the soil to saturate it before runoff begins. Watershed characteristics are important in the relationship of runoff to precipitation. Apparently the water passes through the snow into the ground and through the ground into the streams even when the soil is saturated. Therefore, no dependence can be placed on feeder ditches to intercept snow water unless they actually cut across the lines of flow through the soil.

Studies made in southern California on water supply from rainfall on valley floors showed that for an alluvial valley fill of crystalline origin the distribution and penetration of rainfall moisture over large areas are essentially non-uniform and percolation will concentrate in numerous well defined ducts. Deep penetration may occur during years of deficient rainfall when the maximum consumptive use of the cover is not satisfied. It appears that there is a more or less fixed relation between the seasonal rainfall of a watershed and the consumptive use of its cover which remains approximately the same for kindred watersheds of a region.

In spite of the doubt developed in the past as to the utility of mechanical water finders, it appears that the Bombay Department of Agriculture in India has had some success with an instrument using the principle of the magnetic needle. The conclusion was drawn that under the conditions which prevail in the trap areas of western India, where underground water occurs in well defined streams flowing in rock fissures, sometimes under little or no pressure, and sometimes under considerable pressure, the water finder can be used with advantage in locating streams of water which can be tapped by dug or bored wells.

## DRAINAGE

The cost of drainage is also assuming a position of considerable importance in the total cost of agricultural production in both humid and irrigated areas. The necessity for maximum economy and effectiveness in drainage methods is resulting in efforts to develop practices based upon engineering principles carefully worked out to meet the conditions and requirements presented by individual soils and crops.

The formulation of fundamental conceptions of the problems of drainage seems to have been comparatively recent and very few findings have been reported so far. However, the U. S. Department of Agriculture and the Minnesota, Utah, California, and Washington stations, for example, appear to be giving rather serious consideration to the principles of ground water movement under drainage. The Utah station especially is confronted with the problem of draining irrigated lands overlying artesian basin, and has already established a theoretical physical basis for this practice.

The Washington station in studies of ground water movement in alkali soils found that in the great majority of cases neither the drainage water nor the ground water contained appreciably large quantities of dissolved salts, although where the soil of alkali areas was sampled it contained large quantities of soluble salts, especially in the surface layers. The drainage and underground water from normally productive land was found to be equally as salty as that coming from distinctly alkali areas. The conclusion was drawn that at least a part of the drainage and underground water from alkali areas comes from sources other than through the upper layers of soil.

It is significant that the above studies involve a coordination of the efforts of the forces of soil technology, agronomy, and agricultural engineering and everything indicates that progress in the development of rational drainage principles depends largely on such an organization.

## SOIL EROSION CONTROL AND SOIL MOISTURE CONSERVATION

It appears that the problems of soil erosion and surface runoff prevention and soil moisture conservation call for the development of methods and practices which will meet the characteristics and requirements of individual soils. Work along these lines received considerable impetus during the year and its broadly cooperative aspects seem to have been fully recognized. The economic importance of this work has been well established.

Studies by the Oklahoma station on terracing for soil moisture conservation showed that on heavy soil types an average of only 3.58 inches out of the 17.3 inches of rainfall received annually soaks into the soil and becomes a part of the permanent body of soil moisture. It also appears that runoff conditions may vary sharply even in different parts of the same field. Very slight inequalities of slope cause the accumulation of useless surplus water in low spots and the injurious lack of moisture in the best drained portion of the field. A knowledge of what constitutes proper terracing practice for each soil condition therefore appears to be extremely important.

The work at the Texas station points to the rate of rainfall and the physical condition of the soil as important factors in runoff. Apparently the runoff losses vary considerably under different crops under the same soil, thus bringing in an additional complicating factor. It has also been found that very little slope is required to cause water to flow off the land, and it appears that the greatest beneficial results from water conservation practice can be secured at a minimum cost on comparatively level land. Apparently buffalo grass has been the most effective crop in preventing water losses and when fully sodded is practically perfect in preventing runoff. In this connection overpasturing is a bad practice. Milo, acting as a cover crop while growing and later furnishing a large amount of plant litter, is far superior to cotton in preventing runoff losses. There is also considerable evidence that cultural methods can be improved in handling row crops. It appears that the greatest beneficial result of cultivation is the destruction of weeds, and the results as a whole point to the necessity for further tillage studies.

The Indiana station found that no visible erosion took place in the flow lines of Mangum terraces having a grade of 0.6 per cent or less. Where the clover and timothy sod was light there was slight erosion in the flow line having a grade of 0.7 per cent, but there was none where the sod was heavy. Thus very small variations in slope of terraces are extremely important in determining the erosion of some soils, especially if the cover is light, and the importance of establishing slope limits for different soil conditions with varying degrees of cover seems without question.

## CONCLUSION

The viewpoint on land reclamation seems to have undergone considerable of a change during recent years. It appears that the tendency is now not so much toward the reclamation and agricultural development of waste, timbered, and otherwise marginal lands, but is instead to more or less concentrate on the conservation and better utilization of the resources of the better agricultural lands already available. The U. S. Bureau of Chemistry and Soils, the Texas Agricultural Experiment Station, the U. S. Forest Service and other public agencies have brought attention forcefully to the economics of the situation. It seems necessary, therefore, to establish the proper soil and soil moisture conservation practices for different soil and cropping conditions, by means of a proper coordination of scientific and technical effort, and then to determine where and under what conditions the application of such conservation measures will pay an adequate return.

# Tractors Revolutionize Work on 9000-Acre Hacienda[1]

By Edwin A. Hunger[1]

FOR miles and miles south of the lower Rio Grande in the state of Tamaulipas, Mexico, much of the country is a tangled wilderness of mesquite and cactus. Seventy-four miles southwest from Matamoros, which is across the river from Brownsville, Texas, I recently traveled over a rough road that twined through this wilderness. Habitations were few and far between. Occasionally there would be a clearing of 15 or 20 acres enclosed by a crude brush fence.

And then suddenly the wonderful, big, modernly equipped El Tejon Hacienda spread before my eyes—4,000 acres in cultivation! Three thousand acres are in cotton in rows 1½ miles long, which are worked four and six rows at a time with all-purpose tractors. Eleven of these all-purpose tractors and a standard 15-30-hp. tractor (with which new land is broken at the rate of 1,000 acres a year), together with a variety of up-to-date, tractor-operated machines, makes it possible to operate this big project on a virtually horseless-farming basis. In point of efficiency, equipment, and large-scale operation, this hacienda compares very favorably with the biggest and most modern cotton plantations in the United States. In fact, it reminds one very much of the big cotton ranches in the Corpus Christi region of Texas, which are famed for their large-scale production at low cost by means of tractors and other modern labor-saving equipment, especially four-row tractor planters and cultivators.

Four years ago the land in cultivation on El Tejon Hacienda was a part of the mesquite and cactus wilderness just mentioned. It took some vision and considerable courage to launch a big farming undertaking 'way out in this wilderness. Dionicio Saenz, at present manager of the hacienda, was in charge of a motor truck fleet for M. J. Garcia y Hermanos, prominent merchants of Matamoros. Mr. Saenz is an experienced farmer and had obtained excellent training in power farming in the United States. He was perfectly familiar with methods north of the Rio Grande in clearing big tracts of land of mesquite and planting them in cotton. He had noticed that the land on which the hacienda is now located was more open and not so completely infested with mesquite trees as neighboring sections. He believed, therefore, that the land could be quite easily cleared with modern-day tractor equipment and would profitably produce cotton and other crops. He sold the Garcia brothers on the idea, and so in September 1924 they bought 9,000 acres.

They began to break up the land in the fall of that year with two 10-20-hp. tractors equipped with disk plows. One thousand acres were broken the first year, and the first crop which was largely cotton was planted early in 1925. There are on the new land a lot of running mesquite bushes, as they are called, which have very tangled root systems, and they are very difficult to grub up. Later a larger tractor, a 15-30-hp. unit and special big brush breaking plow (shown in an accompanying illustration) were purchased, and this outfit is largely used to break the new land. About 1,000 acres of new land is put into cultivation each year. The 15-30-hp. tractor has also been used to dig a 4-mile ditch, build roads, and perform other heavy jobs.

The year 1928 was the fourth crop year, and the 4,000 acres were planted as follows: 3,500 acres in Mebane cotton, 200 acres in corn, 300 acres in broom corn, and 80 acres in recently planted orange trees. The cotton yields on an average of one-half bale to the acre.

The eleven all-purpose tractors mentioned provide power for practically all field operations and a number of belt jobs as well. Two of these were purchased in the fall of 1925 and gave such a good account of themselves that the next fall the nine additional units were added to the tractor fleet. Mr. Saenz was very enthusiastic about his tractor fleet. Without tractors he said it would have been impossible to break the land at a profit in the first place and to operate on such a big scale in the second place. The men who are operating these tractors were formerly shepherds or cowboys taken from the neighboring country. None of them previously had had any experience with tractors, but they are able to carry on with apparently little difficulty.

Cotton is the main crop and is planted the latter part of January. It is picked about the middle of June. Corn of a small-eared white variety is planted on this cotton land after the cotton is harvested. This corn is used largely for human consumption in the form of tortillas

[1]Advertising department, International Harvester Co.

(Left) A McCormick-Deering 15-30-hp. tractor pulling a heavy 20-inch brush-breaking plow on El Tejon Hacienda, in the state of Tamaulipas, Mexico, 74 miles southwest of Matamoros, and 30 miles from the Gulf of Mexico. This Hacienda is 9,000 acres in size, 4,000 acres of which are in cultivation. It is owned by M. J. Garcia y Hermanos of Matamoros, and managed by Dionicio Saenz. One thousand acres of new land is being placed in cultivation each year and the land is broken by the outfit shown. (Right) A six-row, "Farmall"-operated cultivating outfit. Unusual efficiencies are obtained on El Tejon Hacienda by the plentiful use of tractor power. There are eleven general-purpose tractors and one 15-30-hp. tractor, which perform all sorts of field and belt jobs with great savings in time and labor. In the illustration, the Farmall is shown in a field of cotton, the rows of which are 1½ miles long

(Left) Corn is an important crop on El Tejon Hacienda. The corn is shelled by a cylinder sheller operated by a tractor as shown. (Right) In off seasons, the tractors and the men are kept busy on El Tejon Hacienda making various improvements, such as roads, ditches, etc. Here a Farmall is shown pulling a scraper on a road-building job

and other Mexican food specialties. In one of the accompanying illustrations, a tractor is shown operating a cylinder corn sheller on El Tejon Hacienda. During the past two years 18,000 bushels of corn have been shelled with this outfit.

Two-row middle busters pulled by the all-purpose tractors are utilized to put the land in condition for cotton. Cotton stalks are broken down by means of disk harrows. Just before planting the cotton, the ridges are worked down by means of a four-section peg-tooth harrow pulled by a tractor. Use is made of six two-row and one four-row planters, all of which are operated by tractor power. Planting is done at the rate of 20 acres a day with the two-row and about 40 acres a day with the four-row planters. All these planters are provided with single-seed drop mechanisms which regulate the planting so that the expensive labor of chopping is obviated.

Thorough and frequent cultivations are an absolute necessity in growing row crops in semi-arid regions such as that in which El Tejon Hacienda is located. The soil on the hacienda is very retentive of moisture, and it is surprising how easy it is to get worth while crops in spite of long intervals between rains. Careful tillage makes possible the retention of a maximum amount of moisture for growing these crops. Until the advent of the all-purpose tractor, cultivation of row crops frequently proved a drawback to large-scale production.

When there are 4,000 acres in row crops as there are on El Tejon Hacienda, and the rows are 1½ miles long, the tractors make it possible to make frequent cultivations with great savings in time and labor. In one of the illustrations is shown a tractor-operated six-row outfit that Mr. Saenz has rigged up for speeding the work. The tractor itself is equipped with a special two-row cultivator which is in front where the driver of the tractor can observe its operation at all times. Then there are two ordinary two-row cultivators, designed for horse operation, hitched to a beam, as shown from the rear. Mr. Saenz also employs a special four-row tractor cultivator. This is the type of cultivator that is being used very extensively in the Corpus Christi region. Only one man is necessary to operate the tractor and this four-row cultivator, and traveling at four miles an hour he is able to cultivate 65 acres a day. With the six-row outfit traveling at that speed almost 100 acres could be covered in a day. Use is also made of six two-row tractor cultivators on the hacienda.

Naturally, much interest is being evinced by Mexican governmental officials in this big modern-day farming project. A recent visitor to the hacienda was His Excellency, Emelio Portes Gil, then governor of the state and more recently president of Mexico, and several members of his staff. He was most enthusiastic about what has been done. Government agricultural engineers are watching the undertaking very closely. Owners of other haciendas have visited El Tejon Hacienda and have gone away convinced that the only way to produce cotton and other crops on a large scale is by the generous use of tractor power and up-to-date, labor-saving equipment.

Results obtained by M. J. Garcia y Hermanos, and their manager, Dionicio Saenz, on El Tejon Hacienda, therefore, presage a new era in farming in northern Mexico, in which tractor power will play a leading role. Fertile land is there by the thousands of acres. With tractors and modern-day, tractor-operated machines it will be a comparatively easy task to put very much of it into profitable production. There is no reason in the world why the appellation "The Magic Valley," which is being used to designate the northern part of the lower Rio Grande Valley, can not refer also to the other side of the river.

(Left) Dionicio Saenz, manager of El Tejon Hacienda, and his interesting family. Mr. Saenz received his training in large-scale, efficient farming by means of up-to-date, labor-saving machines in the United States, and it was largely through his vision and wonderful managerial ability that operations on this big farming project have been successful. (Right) Children of workmen in front of the school house on El Tejon Hacienda. Night schools are also conducted for workmen. Ability to read and write by workmen is considered necessary for the effective operation of this hacienda

# Field and Laboratory Studies of Fertilizer Distributors for Cotton[1]

By G. A. Cumings[2], A. L. Mehring[3], and Ward H. Sachs[4]

MANY types of machines for applying commercial fertilizers are in use at the present time. They vary greatly in design and in the manner of applying the fertilizer. This condition is largely due to insufficient knowledge regarding the factors affecting the operation of the machine and those affecting the efficiency of the fertilizer.

In recent years some careful work has been done on the proper placement of fertilizer in relation to the seed, the factors affecting the drillability (properties affecting distribution) of fertilizer and the operation of distributors. Bibliographies of such work are given by Truog and Jensen[5] and by Mehring and Cumings[6]. The application of fertilizers for greatest efficiency is an intricate problem awaiting solution.

Realizing the importance to agriculture of further information on present methods of mechanically applying fertilizers, the Joint Committee on Fertilizer Application (composed of representatives of the American Society of Agronomy, the American Society of Agricultural Engineers, the National Association of Farm Equipment Manufacturers, and the National Fertilizer Association) in cooperation with Clemson Agricultural College and Experiment Station, and the Bureau of Chemistry and Soils and the Bureau of Public Roads of the United States Department of Agriculture, undertook a study of various types of cotton fertilizer distributing machines.

The purpose of the study was to determine the relative efficiencies of the various types of machines and to secure information which will assist in the development of more efficient distributors. The criteria upon which such comparisons were based included (1) construction and performance of the machines and (2) various effects upon the crop of fertilizers as applied by each machine. The experiments were conducted in South Carolina during the summer of 1929.

**Description of the Distributors.** Twenty-six machines were supplied for the tests by eleven manufacturers. Due to similarity of design, errors in shipment, and breakage, four of the machines were not operated and further reference will not be made to them in this report. Specifications of the remaining 22 machines as equipped for the study are given in Tables I and II. While the distributors differed greatly in many features of design, only eight mechanical principles of fertilizer feed were represented.

The machines tested included 9 simple distributors (fertilizer only) and 13 combination planters and fertilizer distributors. Sixteen of these machines were of the walking type and six of the riding type. The weights of the walking machines with the hopper empty varied from 86 to 176 pounds while the weight of each riding machine was approximately 500 pounds. Hopper capacities ranged from 16 to 100 pounds of a fertilizer having an apparent specific gravity of 1.06. Two of the distributors (Nos. 1 and 4) had wooden hoppers.

Of the seeding mechanisms on the combination machines, ten were of the picker-wheel type and three of the cell-plate type.

**Description of Fertilizers.** Two fertilizers were prepared according to the formulas given in Table III by the F. S. Royster Guano Company at Columbia, S. C. One mixture contained 4 per cent nitrogen, 8 per cent phosphoric acid ($P_2O_5$) and 4 per cent potash and the other was three times as concentrated. The sulphate of ammonia and superphosphate for the 4-8-4 analysis were based 10 days prior to making up the final mixtures. These fertilizers were prepared by screening and mixing in the usual way with standard factory equipment. Table 4 shows the size distribution of the particles of each fertilizer.

## LABORATORY STUDY OF THE MACHINES

The machines were studied in the laboratory relative to uniformity of distribution, effect of inclination of the

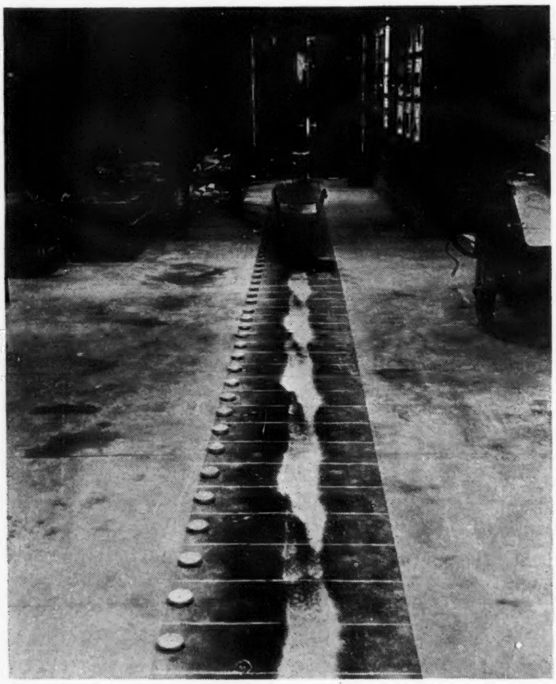


Fig. 1. This picture shows the method of making tests for determining the uniformity of fertilizer distribution

[1]A report of a study of various types of cotton fertilizer distributing machines conducted by the Joint Committee on Fertilizer Application, composed of representatives of the American Society of Agronomy, the American Society of Agricultural Engineers, the National Association of Farm Equipment Manufacturers, and the National Fertilizer Association, in cooperation with Clemson Agricultural College and Experiment Station, and the Bureau of Chemistry and Soils and the Bureau of Public Roads of the U. S. Department of Agriculture. The following contributed to a fund to cover the expenses incidental to the execution of this project. National Fertilizer Association, National Association of Farm Equipment Manufacturers, American Cyanamid Company, The Barrett Company, The N. V. Potash Export My, and the Synthetic Nitrogen Products Corporation. Released for first publication in AGRICULTURAL ENGINEERING.

[2]Agricultural engineer, Bureau of Public Roads, U. S. Department of Agriculture. Assoc. Mem. A.S.A.E.

[3]Associate chemist, Bureau of Chemistry and Soils, U. S. Department of Agriculture.

[4]Assistant director of soil improvement work, National Fertilizer Association.

[5]Truog, E. and Jensen, O. F. Reports and proceedings of the Joint Committee on Fertilizer Application, 1925-8, p. 33-55, National Fertilizer Association, Washington, D. C., 1928.

[6]Mehring, A. L. and Cumings, G. A. Factors Affecting the Mechanical Application of Fertilizers to the Soil. U.S.D.A. Tech. Bul. 182, Washington, D. C., 1930.

TABLE I. Specifications. General design of distributors.

| Machine No. | Number of rows | Weight | Length, walking type | Handles to drive wheel | Drive wheels: Position | Drive wheels: Diameter over-all | Drive wheels: Width of tire | Drive wheels: Kind of tire | Type of drive: Fertilizer mechanism | Type of drive: Seed mechanism | Press wheel tire | Furrow openers: Type: Fertilizer | Furrow openers: Type: Seed | Furrow openers: Means of regulating depth or inclination | Covering devices: Fertilizer | Covering devices: Seed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pounds | Feet | Feet | | Inches | Inches | | | | | | | | | |
| **Simple fertilizer distributors, walking type** | | | | | | | | | | | | | | | | |
| 1 | 1 | 105 | 5.1 | 4.1 | Front | 14.7 | 2.5 | 0.5 inch lugs<br>0.5 inch center flange | Tappet | None | None | None | None | Covering shovel slides | 2 shovels | None |
| 2 | 1 | 107 | 6.3 | 4.8 | Front | 22.7 | 0.9 | Smooth "V" crown | Shaft | None | None | None | None | None | 2 blades | None |
| 3 | 1 | 86 | 5.0 | 1.7 | Rear | 14.2 | 1.8 | Smooth concave<br>0.06 inch center flange | Chain | None | None | Shovel | None | None | None | None |
| 4 | 1 | 96 | 5.3 | 4.1 | Front | 14.7 | 2.0 | 0.4 inch lugs<br>0.4 inch center flange | Tappet | None | None | None | None | None | 2 shovels | None |
| 5 | 1 | 116 | 6.3 | 5.3 | Front | 20.3 | 1.3 | "V" crown<br>0.75 inch lugs | Pitman | None | Concave: solid | None | None | Press wheel adjustment | 2 shovels<br>Press wheel | None |
| 6 | 1 | 116 | 5.5 | 4.3 | Front | 14.5 | 1.8 | 0.3" center cutaway flange | Tappet | None | None | None | None | 2 adjustable carriage wheels | 2 shovels | None |
| 7 | 1 | 122 | 6.4 | 5.5 | Front | 18.2 | 3.0 | Smooth convex | Tappet | None | None | None | None | None | 2 shovels | None |
| 8 | 1 | 94 | 5.3 | 4.0 | Front | 15.1 | 1.8 | Smooth convex | Chain | None | None | None | None | None | 2 shovels | None |
| 22 | 1 | 159 | 5.2 | 4.1 | Front | 14.7 | 1.8 | 0.4 inch center cutaway flange | Shaft | None | None | None | None | 2 bedding disks | 2 shovels<br>2 disks | None |
| **Combination planters and fertilizer distributors, walking type** | | | | | | | | | | | | | | | | |
| 10 | 1 | 152 | 5.7 | 4.7 | Front | 17.4 | 1.5 | 0.6 inch lugs<br>0.6 inch center flange | Pitman | Pitman | Concave: solid | None | Sword | Press wheel adjustment | | 2 blades<br>Press wheel |
| 11 | 1 | 134 | 6.6 | 5.5 | Front | 18.9 | 1.0 | "V" crown<br>0.25 inch lugs | Chain | Chain | Concave: solid | Shovel | Sword | Press wheel adjustment | 2 blades | 2 blades<br>Press wheel |
| 12 | 1 | 136 | 5.9 | 5.0 | Front | 18.5 | 1.1 | "V" crown<br>0.6 inch lugs | Chain | Pitman | Concave: solid | None | Sword | Press wheel adjustment | | 2 blades<br>Press wheel |
| 13 | 1 | 135 | 6.4 | 5.3 | Front | 19.9 | 0.9 | "V" crown<br>0.75 inch lugs | Shaft | Shaft | Concave: open | | Duplex-sword | Press wheel adjustment | 2 blades | 2 blades<br>Press wheel |
| 14 | 1 | 129 | 5.8 | 2.5 | Rear | 20.1 | 5.6 | Smooth concave | Shaft | Shaft | Drive wheel | | Sword | Gage shoe | | Drive wheel |
| 15 | 1 | 176 | 7.1 | 5.7 | Front | 18.5 | 1.1 | "V" crown<br>0.75 inch lugs | Pitman | Pitman | Concave: solid | Shovel | Sword | Press wheel adjustment | | 2 shovels<br>Press wheel |
| 16 | 1 | 142 | 5.0 | 2.5 | Rear | 18.9 | 4.9 | Smooth concave | Pitman | Pitman | Drive wheel | | Sword | Gage shoe | | Drive wheel |
| **Combination planters and fertilizer distributors, riding type** | | | | | | | | | | | | | | | | |
| 9 | 1 | 450 | | None | Sides | 38.6 | 2.5 | Smooth concave | Chain | Shaft | None | Middle buster | Shovel | Adjustable | | 2 shovels |
| 18 | 2 | 500 | | None | Rear | 30.6 | 6.0 | Smoothconcave<br>2.0 inch opening | Chain | Chain | Drive wheel | | Sword | Adjustable | | Drive wheel |
| 19 | 2 | 500 | | None | Rear | 30.6 | 6.0 | Smooth concave<br>2.0 inch opening | Chain | Chain | Drive wheel | | Sword | Adjustable | | Drive wheel |
| 20 | 2 | 500 | | None | Rear | 30.6 | 6.0 | Smooth concave<br>2.4 inch opening | Chain | Chain | Drive wheel | | Sword | Adjustable | | Drive wheel |
| 21 a/ | 2 | 500 | | None | Rear | 30.6 | | Smooth concave<br>2.0 inch opening | Chain | Chain | Drive wheel | | Sword | Adjustable | | Drive wheel |
| **Combination planter and fertilizer distributor, tractor attachment** | | | | | | | | | | | | | | | | |
| 23 | 2 | b/ | | None | Sides | b/ | b/ | b/ | Chain | Chain | Planter wheel | Shovel | Sword | Adjustable | 2 shovels | Planter wheel |

a/ Machine removed by manufacturer before completion of tests b/ Specifications for tractor proper are not pertinent to the study

TABLE II. Specifications. Hopper and feeding mechanism of distributors

| Machine No. | Hopper: Capacity | Hopper: Shape | Hopper: Size at discharge opening | Hopper: Provision for removing hopper wall in cleaning | Feed: Type | Feed: Method of regulating | Feed: Reference for adjustment | Feed: Agitators or stirrers | Delivery tube: Type | Delivery tube: Minimum size |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pounds | | Inches | | | | | | | Inches |
| **Simple fertilizer distributors, walking type** | | | | | | | | | | |
| 1 | 70 | Inverted pyramidal frustrum | 3 x 6.5 | None. Clean from top | Vibrating open-end pan | Angle of pan, gate opening<br>Amplitude of vibration | Pan and gate – none<br>Tappet – 11 holes | None | Steel trough | 1 x 4 |
| 2 | 100 | Inverted pyramidal frustrum | 4.8 x 11 | None. Clean from top | Tapered screw | Screw speed | 9 concentric gears | Vertical pronged spider | Curved spreader | — |
| 3 | 26 | Cylindrical | 7.5 dia. | None. Clean from top | Revolving cylinder<br>Top delivery | Cylinder speed | 7 sprockets for combinations | None | Steel tube | 1.5 dia. |
| 4 | 70 | Inverted pyramidal frustrum | 2.3 x 5.5 | None. Clean from top | Vibrating open-end pan | Angle and opening of pan<br>Amplitude of vibration | Pan – none<br>Tappet – 14 holes | None | Steel tube | 1 x 4 |
| 5 | 35 | Conical frustrum | 11.0 dia. | Loosen 2 nuts (hopper removable) | Revolving plate<br>Deflector gate | Gate opening | 9 notches | 4 arms near plate | Steel tube | 1.5 dia. |
| 6 | 90 | Inverted conical frustrum | 6.3 dia. | None. Clean from top | Oscillating dished plate | Throat opening<br>Amplitude of vibration | Throat – graduated scale<br>Tappet – none | Small projections on plate | None | |
| 7 | 100 | Inverted pyramidal frustrum | 3 x 6 | None. Clean from top | Vibrating curved pan | Gate opening<br>Amplitude of vibration | Gate – none<br>Tappet – two series | None | Six steel tubes | 1.1 x 1.4 each |
| 8 | 75 | Inverted pyramidal frustrum | 4.5 x 5.3 | None. Clean from top | Rectangular orifice<br>Wing agitator | Size of orifice | None | Revolving winged shaft | None | |
| 22 | 60 | Inverted conical frustrum | 6.0 dia. | None. Clean from top | Revolving dished plate | Throat opening | Graduated scale | 1 arm in hopper<br>Throat cleaner | Steel tube | 8.0 dia. |
| **Combination planters and fertilizer distributors, walking type** | | | | | | | | | | |
| 10 | 22 | Cylindrical | 6.3 dia. a/ | Remove 4 bolts | Revolving plate<br>Stationary plow | Throat opening | 17 notches | Conical plate center<br>Throat cleaner | Steel tube | 1.6 dia. |
| 11 | 24 | Cylindrical | 6.0 dia. a/ | Remove 3 bolts | Revolving plate<br>Floating plow | Throat opening<br>Plate speed | Throat – graduations<br>Plate – series sprockets | Conical plate center | Steel tube | 1.5 dia. |
| 12 | 22 | Cylindrical | 8.0 dia. | Remove 2 wing nuts | Revolving plate<br>Deflector gate | Gate opening | Graduations | 5 arms near plate | Spiral steel ribbon | 1.0 dia. |
| 13 | 25 | Cylindrical | 6.0 dia. a/ | Loosen 2 wing nuts (hopper removable) | Revolving plate<br>Stationary plow | Throat opening | Notches, for 13 positions | 2 arms near plate<br>2 arms in hopper | Steel tube | 1.5 x 1.8 |
| 14 | 16 | Cylindrical | 8.3 dia. | Remove 4 bolts | Revolving plate<br>Vertical gate | Gate opening | None | 6 wings on center plate pedestal | Rubberized tube | 0.8 dia. |
| 15 | 25 | Conical frustrum | 9.3 dia. | Remove 3 bolts | Revolving plate<br>Deflector gate | Gate opening | None | 8 lugs near plate<br>4 arms in hopper | Steel tube | 1.5 x 1.8 |
| 16 | 25 | Conical frustrum | 9.3 dia. | Remove 3 bolts | Revolving plate<br>Deflector gate | Gate opening | None | 8 lugs near plate<br>4 arms in hopper | Steel tube | 1.8 dia. |
| **Combination planters and fertilizer distributors, riding type** | | | | | | | | | | |
| 9 | 36 | Cylindrical<br>Tapered base | 4.1 dia. | Loosen 2 wing nuts (hopper removable) | Revolving plate<br>Internal cone | Cone opening<br>Plate speed | Cones – 3 sizes<br>Plate – 2 drive sprockets | None | Spiral steel ribbon | 0.9 dia. |
| 18 | 38 | Conical frustrum | 9.0 dia. | Loosen 2 nuts (hopper removable) | Revolving plate<br>Deflector gate | Gate opening | 9 notches | 4 arms near plate | Steel tube | 1.4 x 2 |
| 19 | 26 | Cylindrical | 9.5 dia. | Remove 2 wing nuts | Revolving plate<br>Deflector gate | Gate opening<br>Plate speed | Gate – graduations<br>Plate – series sprockets | 6 arms near plate<br>1 arm in hopper | Spiral steel ribbon | 1.0 dia. |
| 20 | 35 | Conical frustrum | 6.0 dia. a/ | Loosen 1 wing nut | Revolving plate<br>Stationary plow | Throat opening<br>Plate speed | Gate – graduations<br>Plate – series sprockets | 1 arm on conical platecenter | Steel tube | 1.5 dia. |
| 21 | | | | | | | | | | |
| **Combination planter and fertilizer distributor, tractor attachment** | | | | | | | | | | |
| 23 | 60 | Inverted conical frustrum | 6.0 dia. | None. Clean from top | Revolving dished plate | Throat opening<br>Plate speed | Graduated scale | 1 arm in hopper<br>Throat cleaner | Spiral steel ribbon | 1.0 dia. |

a/ Measurements were not taken at hopper wall but at inner shield integral with hopper. b/ Machine removed by manufacturer before completion of tests.

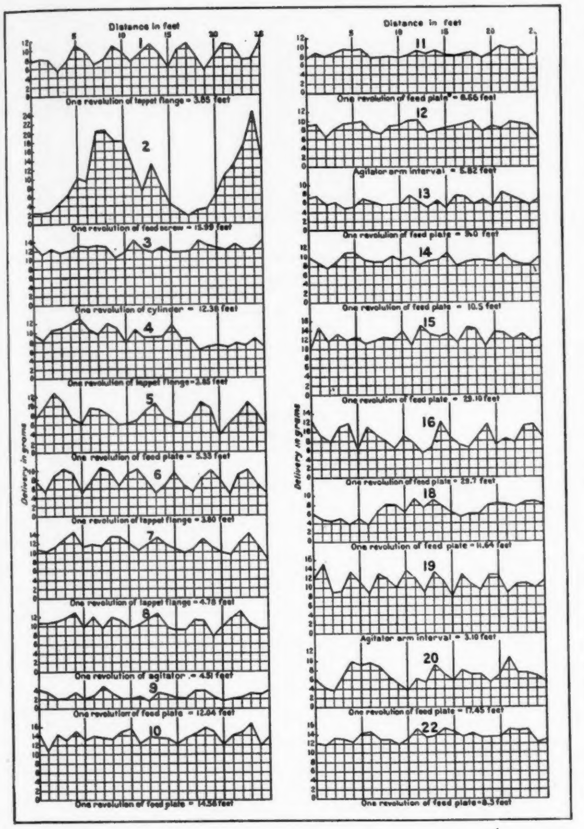



Fig. 2. These are representative delivery curves for the fertilizer distributors tested

machine on delivery rate, variations in delivery rate as the hopper is emptied, and details of construction and specifications of the machines. The laboratory tests dealt only with the distributing mechanism of the machines.

In all of the tests the drillability of the fertilizer was held constant as determined by the angle of repose[7]. Constant drillability was maintained by discarding fertilizer samples the particle size of which had been reduced by action of the distributing mechanism, and by controlling the moisture content. During long periods of high relative humidity is was necessary to dry out the fertilizer frequently. This was most effectively done by spreading the fertilizer in a thin layer on canvas supported off the ground, and exposing it to the sun. During periods of continuous rain the moisture was driven off by artificial heat.

The fertilizers, being composed of large and small particles, segregated somewhat as they were delivered by the machines. In all cases where samples of fertilizer were used a second time they were first thoroughly mixed.

The delivery rates in the laboratory tests were approximately the same as those obtained in the field tests.

Machines 21 and 23 were not tested in the laboratory, while No. 16 was tested only for uniformity of distribution. Machine 21 was removed by the manufacturer before the completion of the tests. The distributing mechanism of Machine 23 is identical in design to that of Machine 22 of the same make used in the tests, and the results obtained for the latter machine may be assumed to apply as well to No. 23. Similarly the results of the laboratory tests of Machine 15 also apply to Machine 16, except as to the uniformity of distribution tests above mentioned.

[7]When a material such as a fertilizer is poured into a pile, the slope of the surface is its angle of repose and this varies inversely with its drillability.

TABLE III. Fertilizer Formulas

| Ingredient | Analysis of ingredient, per cent | | | Quantity used in mixture, pounds | Units of plant food (per cent) | | |
|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | | N | $P_2O_5$ | $K_2O$ |
| | | | Analysis: 4-8-4 | | | | |
| Sulphate of ammonia | 20.5 | | | 260 | 2.67 | | |
| Nitrate of soda | 15.7 | | | 173 | 1.33 | | |
| Superphosphate | | 16.0 | | 1,000 | | 8.00 | |
| Sulphate of potash | | | 48.7 | 164 | | | 4.00 |
| Filler | | | | 403 | | | |
| Total | | | | 2,000 | 4.00 | 8.00 | 4.00 |
| | | | Analysis: 12-24-12 | | | | |
| Ammophos | 10.8 | 48.0 | | 1,000 | 5.40 | 24.00 | |
| Leunasalpeter | 26.0 | | | 507 | 6.60 | | |
| Sulphate of potash | | | 48.7 | 493 | | | 12.00 |
| Total | | | | 2,000 | 12.00 | 24.00 | 12.00 |

**Uniformity of Distribution.** A careful study of the delivery with respect to uniformity of distribution, and an analysis of the causes of any marked variations, were considered important in connection with the project. The quantity variations under laboratory conditions were assumed to closely represent the distribution in the soil and were used as a basis for establishing certain correlations with germination and plant growth determinations.

In making tests on uniformity of distribution the distributors were operated over a mat of composition roofing material 75 feet in length and 3 feet 6 inches in width which was stretched smoothly on a concrete floor (Fig. 1). The mat was ruled at one-foot intervals. The fertilizer delivered was collected in small metal boxes which were numbered consecutively, and was weighed for each of forty successive one-foot intervals. The fertilizer used for the lower delivery rates was the 12-24-12 (angle of repose 41 degrees) and for the higher rates the 4-8-4 (angle of repose 39 degrees).

The uniformity with which the fertilizers were deposited differed somewhat among the distributors as indicated by the analysis of the results in Table V. As observed in Fig. 2, which graphically shows a typical distribution for each machine tested, the prominent impulses of delivery occur at regular intervals in most cases and result from either features of design or irregularities in the shape of certain parts of the distributing mechanism. More or less irregularity of distribution with machines having no perceptible mechanical irregularity indicates that the drilling property of the fertilizer is an important causative factor.

In the case of Distributors 1, 4, 6 and 7 the tappet flange was not accurately centered on the shaft of the drivewheel and the tappet driving the feeding mechanism was thus given a motion of varying amplitude. This resulted in a distinct cycle of delivery for each revolution of the drivewheel. In the cases of the other machines, when prominent impulses occurred at regular intervals they corresponded either with one complete revolution of the dispensing member or with the passage of an agitator arm near the delivery opening. Distributor 2 produced delivery cycles of great amplitude for each revolution of the screw conveyor. If this type of machine were designed with two feed screws so related that the delivery cycles supplemented each other, much more uniform distribution would result. Distributors 5, 8, 12 and 19 show delivery impulses corresponding to the intervals at which agitator arms passed the delivery opening. The graphs showing the results of the tests of Machines 14 and 15 are representative of irregular distribution where no mechanical irregularity of the distributing mechanism is perceptible. Irregular distribution in these cases was a result of the inability of the fertilizer to flow uniformly from the distributing mechanism. This condition was due principally to the physical characteristics of the material and, to some extent, to segregation of the fertilizer in the distributing mechanism according to particle sizes. In the tests of other machines, to which no reference has been made, irregular distribution was caused both by mechanical irregularities and

TABLE IV. Mechanical Analyses

| Screen Mesh | 4-8-4 per cent | 12-24-12 per cent |
|---|---|---|
| 5 - 10 | 9.5 | 13.6 |
| 10 - 20 | 17.7 | 34.1 |
| 20 - 40 | 28.0 | 19.0 |
| 40 - 80 | 21.0 | 11.8 |
| 80 | 23.8 | 21.5 |
| Probable error of determinations | ±0.9 | ±0.4 |

by the physical condition of the fertilizer, but neither effect was predominant.

Considering the coefficient of variability (Table V) which is a percentage measure of the uniformity of distribution, it will be noted that machines of the same type differ greatly—a result of differences in their mechanical imperfections. Irregular distribution resulting from characteristics of design is very strikingly shown in the case of Machine 2.

**Effect of Inclination upon Delivery Rate.** To determine the effect of inclination on delivery rate the distributors were mounted on suitable stands and driven by an electric motor through a set of reduction pulleys at a speed corresponding to an advance of 2.5 miles per hour. Observations on the delivery rate were made by collecting the fertilizer delivered during a certain number of revolutions of the drivewheel. Tests were made with the machine in the normal operating position, inclined 10 degrees forward, and inclined 10 degrees rearward. Tests were conducted at both high and low delivery rates with the 12-24-12 fertilizer (41-degree angle of repose) and the results are presented in Table VI. With the riding or two-wheeled machines, tests were conducted with the machine inclined 10 degrees to either side (Table V11) as well as forward and rearward.

While the results in Table VI indicate that the effect of inclination of the machine on delivery rate is closely related to the type of feed, the effect actually depends upon the location of the delivery opening and the amount of positive action of the distributing mechanism. The vibrator and revolving plate with internal deflector gate types of feed have the delivery opening at the bottom of the hopper wall and in most cases either at the front or rear. Since these machines depend to some extent on gravitational flow of fertilizer for dispensing, they are subject to material changes in delivery rate with changes in inclination. These changes in rate would be greatly reduced by having two agitating pans or deflector gates, according to the type of feed, on opposite sides of the hopper. In this case tilting the machine would increase the rate of one unit but would diminish that of the other. The screw type of feed also has a delivery opening at the bottom and rear of the hopper but being largely positive in action, inclination has little effect on the delivery rate. The rotating wing agitator and revolving plate with internal cone types of feed depend to some extent on gravitational flow of fertilizer for dispensing, but since the delivery opening is near the center of the hopper bottom, inclination has little effect. The revolving dished plate and revolving plate with external plow types of feed have a circular throat (delivery) opening which exerts a compensating influence with changes in inclination, and the delivery rate is little affected. The revolving cylinder top delivery feed is positive in action and thus can not be affected by ordinary changes in inclination.

Considering the effects of lateral inclination of the riding machines on delivery rate, which are shown in Table VII, the explanation given as to forward and rearward inclination for the revolving plate with internal cone and revolving plate with external plow types of feeds also applies in this instance. In the case of the revolving plate with internal deflector gate feed the delivery opening may for this discussion be considered to be at the side of the hopper. When Machine 18 is inclined to the right the feed plate must carry the fertilizer upward toward

TABLE V. Uniformity of Distribution.

| Machine No. | Low Delivery Rate: Mean Lbs/A (a) | Low: Mean Gms/ft | Low: Maximum Gms/ft | Low: Minimum Gms/ft | Low: Standard Deviation Gms/ft | Low: Coefficient of Variability Per Cent | High Delivery Rate: Mean Lbs/A (a) | High: Mean Gms/ft | High: Maximum Gms/ft | High: Minimum Gms/ft | High: Standard Deviation Gms/ft | High: Coefficient of Variability Per Cent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Vibrator (Shaker) Feed | | | | | | |
| 1 | 226 | 8.24 | 11.3 | 5.2 | 1.723 | 20.9 | 659 | 24.02 | 28.6 | 20.6 | 1.913 | 8.0 |
| 4 | 237 | 8.62 | 12.9 | 6.1 | 1.712 | 19.9 | 930 | 33.91 | 43.9 | 25.5 | 4.010 | 11.8 |
| 6 | 215 | 7.83 | 11.2 | 4.7 | 1.886 | 24.1 | 921 | 33.55 | 43.7 | 25.3 | 3.946 | 11.8 |
| 7 | 325 | 11.83 | 14.7 | 8.5 | 1.432 | 12.1 | 981 | 35.76 | 41.6 | 32.1 | 2.069 | 5.8 |
| | | | | | | Revolving plate, internal deflector gate | | | | | | |
| 5 | 229 | 8.34 | 14.0 | 3.5 | 2.276 | 27.3 | 652 | 23.76 | 28.4 | 19.2 | 2.394 | 9.9 |
| 12 | 239 | 8.70 | 10.8 | 6.5 | .970 | 11.1 | 330 | 12.01 | 14.2 | 9.7 | 1.005 | 8.4 |
| 14 | 254 | 9.24 | 11.0 | 7.6 | .943 | 10.2 | 530 | 19.32 | 24.3 | 15.2 | 2.173 | 11.2 |
| 15 | 336 | 12.24 | 14.9 | 9.4 | 1.319 | 10.8 | 769 | 28.02 | 34.7 | 22.6 | 2.722 | 9.7 |
| 16 | 245 | 8.91 | 12.4 | 5.4 | 1.942 | 21.8 | (b) | | | | | |
| 18 | 188 | 6.84 | 9.3 | 3.8 | 1.640 | 24.0 | (c) | | | | | |
| 19-R | 305 | 11.11 | 15.1 | 8.0 | 1.814 | 16.3 | (c) | | | | | |
| 19-L | 296 | 10.78 | 13.5 | 6.7 | 1.493 | 13.9 | (c) | | | | | |
| | | | | | | Revolving dished plate | | | | | | |
| 22 | 369 | 13.43 | 15.1 | 11.7 | .917 | 6.8 | 879 | 32.02 | 35.5 | 27.8 | 1.786 | 5.6 |
| | | | | | | Rotating wing agitator feed | | | | | | |
| 8 | 312 | 11.37 | 16.0 | 7.5 | 1.828 | 16.1 | 916 | 33.37 | 41.8 | 26.7 | 4.285 | 12.7 |
| | | | | | | Screw Feed | | | | | | |
| 2 | 243 | 8.87 | 24.6 | 1.6 | 6.119 | 69.0 | 800 | 29.16 | 62.9 | 5.2 | 18.615 | 63.8 |
| | | | | | | Revolving plate, internal cone feed | | | | | | |
| 9 | 74 | 2.70 | 4.7 | 1.6 | .806 | 29.9 | (c) | | | | | |
| | | | | | | Revolving plate, external plow feed | | | | | | |
| 10 | 380 | 13.86 | 16.6 | 10.6 | 1.123 | 8.1 | 512 | 18.66 | 21.8 | 16.6 | 1.044 | 5.6 |
| 11 | 232 | 8.42 | 10.1 | 7.2 | .671 | 8.0 | 415 | 15.14 | 17.2 | 13.2 | 1.068 | 7.1 |
| 13 | 181 | 6.58 | 9.7 | 4.9 | 1.044 | 15.9 | 483 | 17.60 | 21.1 | 14.8 | 1.619 | 9.2 |
| 20-R | 189 | 6.88 | 10.8 | 3.5 | 1.855 | 27.0 | (c) | | | | | |
| 20-L | 166 | 6.06 | 11.5 | 3.3 | 1.857 | 30.6 | (c) | | | | | |
| | | | | | | Revolving cylinder, top delivery | | | | | | |
| 3 | 336 | 12.26 | 14.2 | 10.1 | 1.140 | 9.3 | 420 | 15.29 | 18.2 | 13.4 | 1.257 | 8.2 |

(a) For convenience as reference (b) Omitted, test conditions indefinite (c) Riding type machines were not tested

the deflector gate; thus the delivery rate is decreased, and vice versa. When Machine 19 is inclined to the right with the feed plate revolving in the direction opposite to that of Machine 18, the fertilizer is carried downward toward the deflector gate and increased delivery results.

**Variation in Delivery Rate.** To determine the variation in delivery rate at intervals as the hopper was emptied the machines were mounted in their normal operating position and driven by a motor as previously mentioned. The hoppers were fully charged with the 12-24-12 fertilizer 41-degree angle of repose and the distributing mechanisms put in motion. The delivery rates, as recorded at intervals of two inches in the depth of fertilizer, are shown in Table VIII.

The variations in delivery rate are highly significant only in a few cases. The factors affecting delivery rate as the hopper is emptied are (1) changes in head of the fertilizer, (2) segregation of particle sizes of the material, and (3) compacting of the fertilizer. With a high-drillability fertilizer of uniform particle size, segregation and compacting would be insignificant, but a gradual decrease in the delivery rate would be expected when the head of fertilizer was decreased. The fertilizer used in these tests did not have high drillability and apparently the delivery rate was not greatly affected by changes in head. The variations noted in the delivery rates are largely due to partial segregation of the particles of different sizes and weights and in some cases to compacting of the fertilizer.

In the hoppers where the fertilizer was vigorously agitated, either by vibration or by stirring, the powdered material collected on the dispensing member. The powdered material on the dispensing member at times retarded the delivery of fertilizer so that the accumulated mass was delivered at irregular intervals, a condition which accounts for the erratic changes in delivery rate.

In a number of instances the delivery rate increased decidedly when the hopper was nearly empty. With only a small amount of fertilizer in the hopper, agitation was very effective and the material being composed of a high percentage of the larger particles as a result of previous segregation, a more rapid flow of fertilizer through the distributing mechanism resulted.

In the top-delivery type of feed (Machine 3) changes in delivery rate are caused almost entirely by the compacting of the fertilizer; since the volume of fertilizer delivered is constant, a gradual increase in delivery rate by weight was noted.

**Construction and Performance.** The machines were in general substantially constructed although a number of minor parts were either vulnerable or did not have sufficient rigidity. The performance and ease of manipulation in the field, which varied in many respects among the machines, was determined by certain features of design and operating conditions.

**Management.** The ease of guiding and handling of the walking type of machine depends to a large extent on the weight and length of the machine and the location of the drivewheel. Little difficulty was experienced with the riding machines in this respect. The weights and lengths of the machines differ considerably as is shown in Table I. It is fully appreciated that the substantiality and functions of a particular type of machine will, within certain limits, determine its weight and length.

No particular difficulty was encountered in guiding or controlling any of the machines on level land or in an open furrow. However, it was difficult to hold some of the combination machines upon a narrow raised seedbed and the task became practically impossible on curved beds which followed contours. The heavy, long machines, particularly those having the drivewheel at the front, would slide off the bed even though the mule driver was adept in keeping the line of draft over the center of the bed. It was observed that the combination machines could be controlled much more easily when the drivewheel was at the rear rather than at the front of the machine. With a shorter horizontal distance from the handles to the center of the wheel, the operator was able to more quickly angle the machine through a wider range to counteract any tendency of leaving the seedbed. Machines 14 and 16, with the drivewheel located at the rear, had also wide concave tires, a fact which may have contributed somewhat to the ease of holding the machine on the raised seedbed.

Machine 15, weight 176 pounds and length 7.1 feet with the drivewheel at the front, was relatively difficult to manage while Machine 16 although heavier than other machines was more easily handled, principally because of its compactness. Machine 7 when fully charged with fertilizer had a high center of gravity and was sometimes difficult to handle.

**Wheel Slippage.** Slippage of the drivewheels was highly significant with all machines, as shown in Table IX. In determining the wheel slippage the revolutions of the wheel were counted as the machine traveled a known distance. The diameter of the wheel as measured from a mean point on the sloping face of the tire was used in determining theoretically the revolutions the wheel should have made. Some factors upon which wheel slippage depended were size of wheel, design and width of tire, weight supported, power required, and character and condition of the soil.

The average wheel slippage according to groups of machines was as follows: Simple distributors, 27 per cent on coarse sand, 17 per cent on sandy clay loam; combination walking machines, 24 per cent on coarse sand, 16 per cent on sandy clay loam; riding machines, 13 per cent on coarse sand. The riding machines were not used on sandy clay loam at Clemson College. The combination walking machines required more power than did the simple distributors, but being heavier and having slightly larger wheels with more lugs on the tires, the wheel slippage on sand was less. Operating conditions were quite different on sandy clay loam, and the influence of greater weight and tire lugs in reducing slippage of the wheel was less significant. Wheel slippage was lowest on the riding machines for the wheels were of greater diameter.

Loose sandy soil offers comparatively little tractive resistance, hence wheel slippage is excessive. The wheel slippage of Machine 2 was relatively low, a condition apparently due to low power requirements and to the fact that the wheel with a narrow tire sank to the firm part of the sedbed.

The wide differences in wheel slippage on the two types of soils clearly indicates the necessity, particularly on loose seedbeds, of calibrating the machines in the field and under the same soil conditions as those under which the machines operate during the tests.

**Hopper Characteristics.** The average hopper capacity was 70 pounds on the simple distributors and 30 pounds on the combination machines. The smallest hopper held 16 pounds (Table II). Such a capacity would not be considered practical where 600 to 800 pounds of fertilizer per acre are applied, as is frequently the case, for too much of the operator's time would be required in refilling the hopper.

The hoppers differ in shape. In previous experiments when using a high-drillability fertilizer, the least effect of changing head on delivery rate was found with those hoppers having a small cross-sectional measurement at the discharge opening. When using a low-drillability fertilizer, less bridging was observed in hoppers larger at the bottom than at the top. With the kind of fertilizer used in the present experiments, however, no consistent variations due to the shape of hopper were apparent.

In a number of machines the hoppers were not readily accessible for thorough cleaning of the distributing mechanism, as is shown by the arbitrary ratings given in Table IX. Although Machines 1, 4, 6, 7 and 22, as indicated in Table II, had no provision for disassembling the hopper for cleaning, they were easily cleaned because of their simplicity.

Distributors 2 and 8 were difficult to clean because the bottom of the hopper was inaccessible. Other machines, such as Nos. 10, 15 and 16 could not be readily cleaned because in disassembling several bolts had to be removed and then the hopper walls only could be lifted off. In separating the hopper wall from the base any appreciable amount of fertilizer remaining in the hopper was free to flow out onto the machine and ground. Machines con-

TABLE VI.

EFFECT OF INCLINATION OF DISTRIBUTOR ON DELIVERY RATE

| Machine | Delivery | | | | | | Increase or decrease from normal rate | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low Rate | | | High Rate | | | Low Rate | | High Rate | | Average | |
| No. | Forward 10° | Normal | Rearward 10° | Forward 10° | Normal | Rearward 10° | Forward 10° | Rearward 10° | Forward 10° | Rearward 10° | Forward 10° | Rearward 10° |
| | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Percent | Percent | Percent | Percent | Percent | Percent |
| | | | | Vibrator (Knocker) feed | | | | | | | | |
| 1 | 97 | 304 | 495 | 360 | 912 | 1245 | -68 | +63 | -60 | +37 | -64 | +50 |
| 4 | 182 | 238 | 388 | 774 | 1086 | 1713 | -23 | +63 | -29 | +58 | -26 | +60 |
| 6 | 281 | 338 | 535 | 1137 | 1163 | 1513 | -17 | +58 | - 2 | +30 | -10 | +44 |
| 7 | 228 | 340 | 405 | 770 | 907 | 1006 | -33 | +19 | -15 | +11 | -24 | +15 |
| | | | | Revolving plate, internal deflector gate | | | | | | | | |
| 5 | 182 | 244 | 244 | 606 | 684 | 746 | -25 | 0 | -11 | + 9 | -18 | + 5 |
| 12 | 241 | 264 | 299 | 299 | 341 | 382 | - 9 | +13 | -12 | +12 | -11 | +13 |
| 14 | 275 | 263 | 237 | 770 | 621 | 538 | + 5 | -10 | +24 | -13 | +14 | -12 |
| 15 | 339 | 264 | 190 | 698 | 568 | 416 | +28 | -28 | +23 | -27 | +26 | -27 |
| 18 | 426 | 376 | 359 | (1) | | | +13 | - 4 | (1) | | +13 | - 4 |
| 19 | 291 | 275 | 221 | (1) | | | + 6 | -20 | (1) | | + 6 | -20 |
| | | | | Revolving disked plate | | | | | | | | |
| 22 | 248 | 290 | 313 | 847 | 856 | 886 | -14 | + 8 | - 1 | + 4 | - 8 | + 6 |
| | | | | Orifice, Wing agitator feed | | | | | | | | |
| 8 | 352 | 361 | 413 | 819 | 882 | 898 | - 2 | +14 | - 7 | + 2 | - 5 | + 8 |
| | | | | Screw feed | | | | | | | | |
| 2 | 267 | 288 | 309 | 832 | 877 | 932 | - 7 | + 7 | - 5 | + 6 | - 6 | + 7 |
| | | | | Revolving plate, internal cone feed | | | | | | | | |
| 9 | 123 | 127 | 134 | (2) | | | - 3 | + 6 | (2) | | - 3 | + 6 |
| | | | | Revolving plate, external plow feed | | | | | | | | |
| 10 | 259 | 259 | 268 | 611 | 590 | 596 | 0 | + 4 | + 4 | + 1 | + 2 | + 2 |
| 11 | 251 | 238 | 243 | 417 | 407 | 406 | + 6 | + 2 | + 3 | 0 | + 4 | + 1 |
| 13 | 293 | 285 | 288 | 578 | 524 | 528 | + 3 | + 1 | +10 | + 1 | + 7 | + 1 |
| 20 | 373 | 356 | 344 | (1) | | | + 5 | - 3 | (1) | | + 5 | - 3 |
| | | | | Revolving cylinder, top delivery | | | | | | | | |
| 3 | 264 | 262 | 260 | 444 | 443 | 444 | + 1 | - 1 | 0 | 0 | + 1 | 0 |

(1) Two-row machines were not tested (2) Maximum delivery is given under low rate

TABLE VII. Effect of Lateral Inclination of Riding Distributors Upon Delivery Rate

| Distributor number | Delivery | | | Increase or decrease from normal rate | |
|---|---|---|---|---|---|
| | Right, 10° Pounds per acre | Normal (level) Pounds per acre | Left, 10° Pounds per acre | Right, 10° Pounds Per cent | Left, 10° Pounds Per cent |
| | | Revolving plate, internal-cone feed | | | |
| 9 | 119 | 127 | 135 | -6 | +6 |
| | | Revolving plate, internal deflector gate feed | | | |
| 18 | 375 | 386 | 450 | -3 | +17 |
| 19 | 292 | 275 | 243 | +6 | -12 |
| | | Revolving plate, external plow feed | | | |
| 20 | 344 | 356 | 353 | -3 | - 1 |

veniently cleaned were those on which the entire hopper was hinged or removable, and, in addition, the hopper could be readily disassembled.

Thorough cleaning of the distributing mechanism is advisable because fertilizer readily absorbs moisture thus causing the fertilizer to cake and the metal parts to corrode rapidly. Considerable difficulty was experienced with Machine 14 since, notwithstanding thorough cleaning of the snug-fitting feed plate, sufficient corrosion occurred over night to prevent the plate from turning, and the mechanism had to be partially disassembled before the machine could be operated. No difficulty was experienced in this respect with other similar types of machines such as Nos. 15 and 16, for the feed plate was more loosely fitted and was so designed that any fertilizer getting under the plate would be mechanically discharged.

Machine 5 having a flat feed plate with no provision for the fertilizer collecting under the plate to escape, and having but little clearance between the upper surface of the plate and the deflector gate, did not operate satisfactorily. The plate was raised against the deflector gate and due to the friction and binding there was insufficient traction of the drivewheel in the field to turn the plate.

Among other difficulties experienced was the inability to remove carriage bolts about the hopper and adjustments. It was necessary in a number of instances to sever the bolt after the nut became rust-bound, for the shoulder when fitted loosely in a slot failed to prevent the bolt from turning. In other cases bolt heads or nuts were practically inaccessible for holding or turning with a wrench.

**Delivery Rate Adjustment.** Adjustment for delivery rate is an important consideration in the design of a distributor. Very few of the machines were above criticism with respect to delivery rate adjustment.

Where the delivery rate was regulated only by changing gears or sprockets, or by shifting the gate adjustment into notches, usually the intervals of delivery rate adjustment were too great, running as high as 200 or more pounds per acre. In most cases where the delivery rate could be regulated by a gradual movement of the gate or throat adjustment, a slight movement of the adjustment made a material difference in the delivery rate. In the case of Machine 7 moving the wide fertilizer gate approximately 1/16 inch changed the delivery rate 200 pounds per acre. In many instances the adjustments had either reference scales so indistinct as to be of little benefit, or no reference points of any kind. During the experimental work it was necessary to place some points of reference on the adjustments. Reference points were essential for ready adjustment in obtaining desired rates of application.

The kind of delivery rate adjustment is determined largely by the type of distributing mechanism, but the convenience of changing them differs greatly with the various machines. The use of a series of sprockets is not convenient for they are likely to get lost, a wrench is required for their removal, and the length of chain must also be varied. A limited number of gears or sprockets supplemented by another adjustment is not objectionable, for they are seldom changed. On Machine 11 the seed plate was operated from the fertilizer driveshaft; thus when changing sprockets for the fertilizer feed, the rate of seeding was altered and also had to be corrected. The beveled pinion for driving the fertilizer plate on Machine 11, also used to disengage the drive, was held in mesh by a light spring, but held out of mesh by a positive adjustment. The resistance offered by the distributing mechanism frequently caused the drive pinion to disengage itself. While such an arrangement serves admirably as a safety device, less difficulty would be experienced during operation if the gears were positively held in mesh. On Machine 10 the fertilizer mechanism could not be disengaged, which is an objectionable feature.

On a number of machines, square nuts were used in connection with delivery rate adjustments which required the use of a wrench. Winged nuts in many cases soon corroded, necessitating the use of pliers or wrench for loosening or tightening. The most convenient adjustments were those accomplished by shifting the adjustment lever from one notch to another.

Machines 6, 10, 22 and 23 had adjustments moving through a wide range with distinct graduations or notches numbered at intervals which proved to be quite satisfactory. Delivery rates may be more accurately controlled where two independent adjustments are provided. Nothing is to be gained by giving the number of pounds per acre on the reference scale, since the drillabilities and apparent specific gravities of fertilizers vary so widely.

Although Machine 10 had a satisfactory delivery rate adjustment, the feed plow was made of light sheet metal and held in place by one stove bolt. The plow was easily bent or moved out of place and, as a result, the delivery rate was changed.

Types of distributors depending partially on the force

TABLE VIII. Variation in Delivery Rate as Hopper is Emptied.

Distributors by type of feed and by number.

| (1) Depth of fertilizer in hopper | Vibrator (knocker) | | | | Revolving plate, internal deflector gate | | | | | | Revolving dished plate | Rotating wing agitator | Screw | Revolving internal cone | Revolving plate, external plow | | | | Revolving cylinder, top delivery. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | 6 | 7 | 5 | 12 | 14 | 15 | 18 | 19 | 22 | 8 | 2 | 9 | 10 | 11 | 13 | 20 | 3 |
| | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A | Lbs/A |
| | | | | | | | | | Low Rate | | | | | | | | | | |
| 16 | 364 | 244 | 343 | 353 | | | | | | | 281 | 276 | | 126 | | | | | |
| 14 | 291 | 234 | 341 | 369 | | | | | 389 | | 280 | 274 | 294 | 130 | | | | | 241 |
| 12 | 270 | 238 | 336 | 388 | 185 | | | 272 | 397 | | 289 | 273 | 296 | 131 | 278 | 236 | 247 | 355 | 258 |
| 10 | 260 | 240 | 338 | 359 | 160 | 264 | | 258 | 397 | | 300 | 268 | 296 | 123 | 276 | 238 | 273 | 359 | 262 |
| 8 | 270 | 239 | 329 | 332 | 161 | 264 | 270 | 266 | 376 | 288 | 291 | 268 | 294 | 127 | 271 | 244 | 268 | 356 | 263 |
| 6 | 248 | 247 | 349 | 328 | 165 | 264 | 266 | 267 | 387 | 275 | 288 | 274 | 294 | 127 | 269 | 233 | 293 | 353 | 264 |
| 4 | 275 | 274 | 369 | 325 | 150 | 264 | 261 | 285 | 369 | 268 | 294 | 282 | 293 | 128 | 268 | 251 | 305 | 347 | 265 |
| 2 | 349 | 328 | 385 | 297 | 165 | 264 | 258 | 294 | 381 | 260 | 284 | 345 | 297 | 124 | 264 | 261 | 220 | 288 | 271 |
| Ave. | 291 | 256 | 349 | 344 | 164 | 264 | 264 | 274 | 385 | 273 | 288 | 283 | 295 | 127 | 271 | 244 | 268 | 343 | 261 |
| | | | | | | | | | High Rate | | | | | | | | | | |
| 16 | 931 | 1095 | 1156 | 894 | | | | | (2) | (2) | 836 | 852 | | (2) | | | | (2) | |
| 14 | 894 | 1075 | 1143 | 894 | | | | | | | 851 | 870 | 855 | | | | | | 428 |
| 12 | 862 | 1097 | 1150 | 910 | 748 | | | 572 | | | 860 | 870 | 862 | | 599 | 396 | 506 | | 432 |
| 10 | 812 | 1097 | 1143 | 907 | 750 | 339 | | 565 | | | 862 | 885 | 862 | | 568 | 397 | 523 | | 434 |
| 8 | 765 | 1095 | 1172 | 891 | 734 | 345 | 640 | 562 | | | 847 | 879 | 862 | | 605 | 405 | 521 | | 441 |
| 6 | 741 | 1118 | 1179 | 902 | 722 | 339 | 623 | 574 | | | 851 | 898 | 863 | | 602 | 419 | 528 | | 443 |
| 4 | 659 | 1118 | 1189 | 889 | 729 | 339 | 621 | 570 | | | 840 | 892 | 867 | | 591 | 435 | 510 | | 443 |
| 2 | 685 | 1144 | 1225 | 878 | 736 | 339 | 600 | 553 | | | 711 | 1122 | 899 | | 580 | 435 | 412 | | 450 |
| Ave. | 794 | 1105 | 1170 | 896 | 737 | 340 | 621 | 566 | | | 832 | 909 | 867 | | 591 | 415 | 500 | | 439 |

(1) Depths of hoppers vary from 9.5 to 20 inches. (2) Riding type distributors were not tested

TABLE IX. Operating characteristics of distributors

| Machine No. | Wheel slippage: Coarse sand | Wheel slippage: Sandy clay loam | Maximum delivery rate on sandy soil | Rating for cleaning hopper a/ | Position from which feed is visible | Visibility of fertilizer entering soil |
|---|---|---|---|---|---|---|
| | Per cent | Per cent | Pounds per acre | | | |
| **Simple distributors, walking type** | | | | | | |
| 1 | 30.8 | 21.2 | 2,948 b/ | Very good | Operator | Good |
| 2 | 9.8 | 5.1 | 1,268 | Very poor | Operator | Good |
| 3 | 35.1 | 13.5 | 276 | Good | Operator | Fair |
| 4 | 29.8 | 17.2 | 1,912 b/ | Very good | Operator | Good |
| 5 | 38.9 | 24.7 | 826 | Fair | Operator | Good |
| 6 | 18.9 | 15.5 | 1,950 b/ | Very good | Operator | Good |
| 7 | 21.6 | 14.6 | 2,830 b/ | Very good | Operator | Good |
| 8 | 33.2 | 18.4 | 3,080 | Poor | Operator | Good |
| 22 | c/ | 21.3 | c/ | Very good | Operator | Good |
| **Combination machines, walking type** | | | | | | |
| 10 | 21.5 | 14.6 | 367 | Poor | Side | Good |
| 11 | 22.6 | 16.9 | 407 | Fair | Side | Obstructed |
| 12 | 21.1 | 11.4 | 290 | Poor | Side | Fair |
| 13 | 27.4 | 14.8 | 541 | Good | Side | Obstructed |
| 14 | 22.4 | 16.5 | 465 | Fair | Front | Fair |
| 15 | 27.5 | 17.0 | 539 | Poor | Front | Obstructed |
| 16 | 23.9 | 19.9 | 376 | Poor | Front | Fair |
| **Combination machines, riding type** | | | | | | |
| 9 | 9.3 | d/ | 120 | Very good | Enclosed | Fair |
| 18 e/ | | | | Fair | Front | |
| 19 | 13.1 | d/ | 505 | Poor | Front | Fair |
| 20 | 17.8 | d/ | 348 f/ | Fair | Front | Fair |
| 21 g/ | 10.0 | | | | Side | Fair |

a/ Based on accessibility and ease of thorough cleaning
b/ Maximum rate at medium agitation
c/ Not used in tests on coarse sand at Sand Hill Station
d/ Not used in tests on sandy clay loam at Clemson College
e/ Not operated in the field
f/ Special drive sprocket supplied for a higher rate
g/ Machine removed by manufacturer before completion of tests

of gravity for their operation and having a wide gate for controlling the delivery of fertilizer could not be satisfactorily adjusted at the lower delivery rates. In order to obtain a low rate it was necessary to move the gate close to its seat thus reducing the gate opening to a narrow slit. Most fertilizers bridge readily over a narrow opening, and as a result flow irregularly and coarse particles can not pass through the opening. It would be preferable in such cases to have the same area of opening in a form approaching a square or circle.

**Maximum Delivery Rate.** The maximum delivery rates as determined by actual field tests on coarse sandy soil with a fertilizer having a drillability corresponding to an angle of repose of 39 degrees are given in Table IX. The average maximum rate was 1886 pounds per acre for the simple distributors and 426 pounds per acre for the combination machines excluding Machine 9. Machine 9, having a maximum rate of 120 pounds per acre, was not designed for the southeastern cotton section. None of the combination machines met the requirements of the grower who wishes to apply 600 or more pounds of fertilizer per acre, while some did not apply as much as the average rate of application.

Laboratory calibrations are likely to be misleading unless wheel slippage, inclination of the machine, and condition of the fertilizer are taken into consideration. In the field narrow wheels on walking machines sink into a soft seedbed and incline the machine forward while in other cases the covering shovels are likely to sink into the soil and incline the machine rearward. Suitable depth-regulating devices should be attached at the rear of the machine. Narrow slides attached to the covering shovels on Machine 1 were not effective in holding the shovels at the desired depth. In preliminary tests, Machine 1 was adjusted in the laboratory for 800 pounds per acre, but when operated in the field by a farm laborer who permitted the covering shovels to run too deeply thus inclining the machine rearward, the delivery rate was more than 2,000 pounds per acre.

**Visibility of Feed.** As shown in Table IX the fertilizer feed was not visible from the operator's position on 50 per cent of the machines, but the fertilizer could be seen as it entered the soil in all except three instances. It is desirable that the operator be able to observe the delivery of fertilizer at all times.

TABLE X. Rainfall During Planting and Germination

| Sand Hill Experiment Station, South Carolina: Period of 24 hours ending at 8:00 a.m. | Rainfall, inches | Clemson College South Carolina: Period of 24 hours ending at 8:00 a.m. | Rainfall, inches |
|---|---|---|---|
| April 11 | 0.73 | | |
| " 16 | 0.95 | May 14 | 0.40 |
| " 20 | 0.02 | " 15 | .40 |
| " 21 | .19 | " 16 | 1.75 |
| " 25 | 1.03 | " 19 | .38 |
| " 29 | 1.00 | " 20 | .83 |
| May 1 | .55 | " 27 | .81 |
| " 2 | .99 | " 29 | .13 |
| " 3 | .61 | " 30 | .02 |
| " 7 | .55 | June 1 | .10 |
| " 9 | .05 | " 2 | .03 |
| " 17 | .25 | " 3 | .30 |
| " 20 | .76 | " 8 | .02 |
| " 21 | 1.37 | " 9 | .02 |
| " 27 | .21 | " 15 | .01 |
| " 28 | .71 | " 18 | .01 |
| " 30 | .34 | | |
| " 31 | .09 | | |
| June 3 | .15 | | |
| " 4 | .13 | | |
| " 9 | .75 | | |
| " 10 | .42 | | |
| " 11 | .05 | | |

The delivery tubes on several machines were so small that clogging would probably occur under adverse conditions.

**Covering Devices.** Covering devices, both blade and shovel, on the combination machines gathered trash and clogged the machine under the soil conditions of the test. Covering devices were found to be unnecessary for the field tests to be described later, and were removed. The small press wheels, approximately 9.5 inches in diameter and 5.0 inches wide, in some cases failed to rotate on loose sandy soil and as a result soil and trash gathered in front of them and clogged the machine. Reducing the weight on the press wheel by bearing up slightly on the handles obviated this difficulty.

In attempting to plant the seed at a uniform depth of one inch or less, difficulty was experienced with some of the machines. Greatest accuracy was possible when the seed shoe was free to follow the surface of the seedbed and was equipped with suitable depth gages. Fenders for the seed shoe are also an advantage in loose soil. A long machine supported by a drivewheel in front and a press wheel at the rear does not deposit the seed or fertilizer at a uniform depth on irregular seedbeds. Machine 9, of the riding type, had covering shovels supported by a chain from the main frame; thus the depth of penetration varied with the irregularity of the ground upon which the wheels were traveling, regardless of the corresponding relative height of seedbed. The loose, sandy soil would not support the runners of the two-row planters for planting at a depth of 1 inch; thus most of the weight of the runner frame had to be carried by the planter. This resulted in the runner frame being suspended at the center and free to swing laterally; consequently the shoes seldom ran at the same depth.

**Fertilizer Placement.** The placement of the fertilizer in relation to the seed and the degree of mixing with the soil were observed by careful cross-sectioning of the seedbed. Special tests were conducted in which various pigments were mixed with the fertilizer and it was found that light blue afforded the strongest contrasts with the brown soil. Fig. 3 shows sketches representing the cross-section of the seedbed and indicating the relative position of fertilizer and seed as deposited by all machines except No. 18 which was not operated in the field.

The simple distributors placed the fertilizer in the bottom of an open furrow in bands of varying widths. In covering the fertilizer with soil the covering shovels carried the outer portions of the fertilizer band toward the center and this portion of the fertilizer became somewhat mixed with the soil. The amount of fertilizer turned towards the center depended upon the design and spacing of the covering shovels. The wide bands were naturally most affected. The undisturbed portion of the fertilizer for each distributor lay approximately 2 inches below the seed.

With the combination machines the placement and distribution of the fertilizer varied according to the design and arrangement of the furrow openers. Certain machines did not place the fertilizer exactly as would have been supposed from the design of the shoes or attachments. In some cases the soil failed to flow into the furrow and separate the seed and fertilizer as intended, while in other cases the fertilizer either flowed by gravity or was carried by the covering devices to points nearer the seed.

## FIELD TESTS

**Methods of Procedure.** The soils selected were Norfolk coarse sand at the Sand Hill Experiment Station located on the Coastal Plain near Columbia, South Carolina, and Cecil sandy clay loam at Clemson College, South Carolina, in the Piedmont:

In conducting the field tests eight plantings were made at intervals of approximately one week between April 3 and May 25. During this period soil conditions changed, thus affecting wheel slippage and the conditions of the fertilizer varied somewhat, making it necessary to calibrate the machines under actual working conditions in the field prior to each planting in order that the delivery rate for each machine might be as near as possible that desired. Laboratory calibrations served only as a rough guide for the field work on account of the significant variations resulting from wheel slippage and changes of operating conditions.

Changing the inclination of certain types of machines has a marked effect on the delivery rate as shown in Table VI. To reduce this variability to a minimum, particularly in the case of machines free to tilt forward or rearward, the same man carefully operated all machines throughout the calibrating and testing.

The drilling properties of a fertilizer change rapidly when exposed to ordinary atmospheric conditions. Endeavoring to maintain the drillability constant throughout any given planting, a quantity of each fertilizer was thoroughly mixed prior to each planting and weighed into paper bags as rapidly as consistent with accuracy, so that it would not have time to dry out or absorb moisture. The 4-8-4 fertilizer was divided into 25-pound lots and the 12-24-12 into 20-pound portions. These bags were then tied and enclosed in moisture-resistant bags which were not thereafter opened until used. For each calibration or test of a machine one sack of fertilizer was placed in the hopper. The weight of material remaining in the hopper at the end of a measured row was determined, thus the quantity applied was definitely known.

The angles of repose of the 4-8-4 fertilizer were 40, 41 and 43 degrees, and of the 12-24-12 fertilizer 40, 41, and 45 degrees during the sixth, seventh and eighth plantings, respectively. The results of only these three plantings are presented in this paper for reasons given hereafter.

The rates of application desired were 800 pounds per acre of the 4-8-4 fertilizer and 267 pounds per acre of the 12-24-12 fertilizer. It was not possible to obtain the desired delivery rates exactly in most cases because, as previously stated, delivery rates varied somewhat with changing operating conditions, and furthermore on a number of machines a slight movement of the fertilizer gate produced a marked change in delivery rate, while on others the rate adjustments were fixed at intervals as large as 200 pounds per acre. The rates actually obtained in each test are given in Tables XI, XII and XIII.

Plots were carefully selected at each station to obtain uniform soil conditions. Seedbeds were prepared in the usual manner. Furrows were opened 3.5 feet apart. When necessary a large sweep was used to smooth the furrow and drag in sufficient soil to give the desired depth. Before operating those machines which deposit the fertilizer in an open furrow a wooden slab was dragged along the furrow to remove projections, fill depressions and thus insure a uniform depth of soil over the fertilizer applied.

The simple distributors were tested with both ordinary and concentrated fertilizers while the combination machines due to their inability to deliver at the rate of 800 pounds per acre were tested only with 12-24-12 material.

Fertilizer was applied by each machine in two rows 124.5 feet in length and located some distance apart according to the replication plans. A bag of fertilizer was placed in the hopper and the machine was drawn by two mules. Precautions were taken to prevent the mules as well as the operator from stepping on the test rows. At the end of the first row the machine was thrown out of gear for transporting to the second row. At the end of the test the machine was thoroughly cleaned and the remaining fertilizer weighed.

Every fourth row throughout any series of tests was left unfertilized as a check, but in all other respects they were treated in the same manner as the fertilized rows.

In addition to the unfertilized check rows, two rows in each planting were fertilized in the manner described below to serve as checks against the uniformity of fertilizer distribution in the machine-fertilized rows. The desired quantity of fertilizer for each yard of row was weighed into paper bags prior to distribution. Each bag of fertilizer was then carefully distributed by hand over one yard of row as determined by a marked chain laid in the furrow and thus uniformity was practically insured throughout the entire row. Where the fertilizer and seed were applied separately beds were made by turning soil over the fertilizers that had been applied in open furrows. The tops of these beds were lowered to a uniform height of 3 inches above the fertilizer previous to seeding by means of a wooden drag which consisted of a 2-foot board bolted to a Georgia plow stock.

The seedbed for the combination machines was pre-

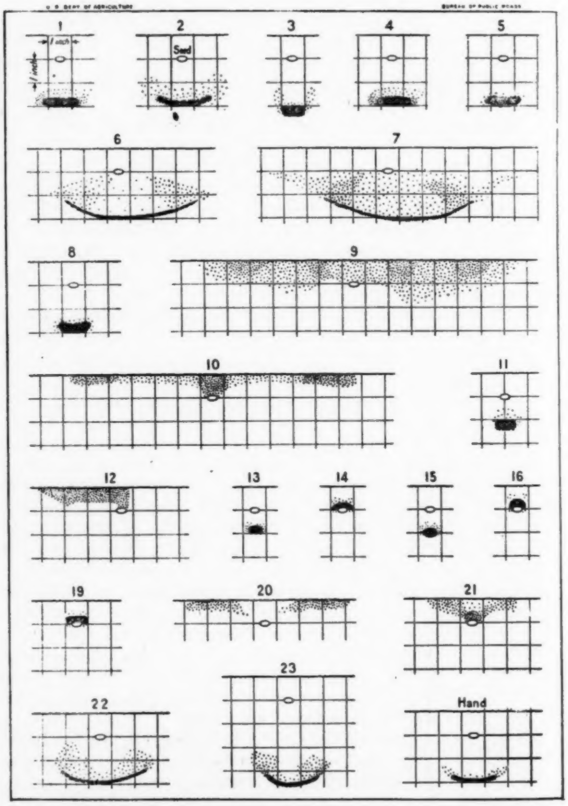



Fig. 3. Placement of the fertilizer in relation to the seed

TABLE XI. Effect of fertilizers, as applied by various types of machines, on cotton planted May 5, 1929 in Norfolk coarse sand containing 5.3% moisture.

| Machine Number | Application Rate May 9 | Number of Replications | Germination: Average number per plot (36-ft row) May 17 | May 22 | May 29 | June 11 a/ | Germination: Ratio of fertilized to unfertilized May 17 | May 22 | May 29 | June 11 a/ | Average Length of Plants July 9 | Number of Blooms per plot July 18 to Aug. 3 inc. | Yields of Seed Cotton Oct. 10 | Nov. 8 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. per acre | | | | | | Per cent | Per cent | Per cent | Per cent | Inches | | Lbs. per acre | Lbs. per acre | Lbs. per acre |
| **Seed and 4-8-4 fertilizer planted in separate operations** | | | | | | | | | | | | | | | |
| 1 | 794 | 4 | b/ | 64 | 358 | 332 | b/ | 27 | 98 | 100 | 12.3 | 174 | 781 | 40 | 821 |
| 2 | 767 | 4 | | 123 | 354 | 334 | | 51 | 96 | 100 | 11.2 | 194 | 660 | 38 | 698 |
| 4 | 752 | 4 | | 35 | 366 | 333 | | 15 | 100 | 100 | 10.8 | 148 | 670 | 66 | 736 |
| 5 | 821 | 4 | | 103 | 334 | 301 | | 43 | 91 | 90 | 12.6 | 191 | 735 | 59 | 794 |
| 6 | 831 | 4 | | 62 | 318 | 310 | | 26 | 87 | 93 | 10.2 | 123 | 612 | 73 | 685 |
| 7 | 832 | 4 | | 19 | 370 | 341 | | 8 | 101 | 102 | 10.6 | 100 | 501 | 62 | 563 |
| 8 | 735 | 4 | | 99 | 355 | 338 | | 41 | 97 | 101 | 12.6 | 188 | 623 | 39 | 662 |
| Uniform Hand Distribution c/ | 800 | 4 | | 41 | 342 | 311 | | 17 | 93 | 93 | 13.1 | 202 | 832 | 29 | 861 |
| No Fertilizer | None | 14 | | 242 | 366 | 333 | | | | | 7.5 | 1 | 30 | 35 | 65 |
| **Seed and 12-24-12 fertilizer planted in separate operations** | | | | | | | | | | | | | | | |
| 1 | 307 | 4 | | 148 | 331 | 305 | | 58 | 92 | 91 | 9.6 | 102 | 540 | 47 | 587 |
| 2 | 250 | 4 | | 181 | 322 | 285 | | 70 | 89 | 85 | 10.2 | 82 | 356 | 48 | 404 |
| 3 | 258 | 4 | | 138 | 307 | 277 | | 54 | 85 | 83 | 12.1 | 109 | 388 | 43 | 431 |
| 4 | 305 | 4 | | 59 | 273 | 241 | | 23 | 76 | 72 | 12.6 | 132 | 488 | 45 | 533 |
| 5 | 320 | 4 | | 176 | 288 | 260 | | 68 | 80 | 78 | 10.5 | 135 | 437 | none | 437 |
| 6 | 259 | 4 | | 48 | 311 | 266 | | 19 | 86 | 79 | 11.0 | 125 | 387 | " | 387 |
| 7 | 263 | 4 | | 78 | 272 | 229 | | 30 | 76 | 68 | 10.8 | 82 | 269 | " | 269 |
| 8 | 227 | 4 | | 155 | 301 | 279 | | 60 | 84 | 83 | 10.9 | 147 | 415 | " | 415 |
| Uniform Hand Distribution c/ | 267 | 4 | | 71 | 279 | 257 | | 28 | 77 | 77 | 14.6 | 129 | 640 | 41 | 681 |
| No Fertilizer | None | 12 | | 257 | 361 | 339 | | | | | 7.4 | 1 | 32 | 32 | 64 |
| **Seed and 12-24-12 fertilizer planted in one operation** | | | | | | | | | | | | | | | |
| 9 | 120 | 8 | 137 | 257 | 278 | 238 | 80 | 77 | 83 | 87 | 9.0 | d/ | 191 | none | 191 |
| 9 No Fertilizer | None | 8 | 172 | 335 | 335 | 274 | | | | | 8.4 | | 13 | " | 13 |
| 10 | 252 | 8 | 46 | 176 | 240 | 224 | 33 | 48 | 57 | 58 | 9.1 | | 268 | " | 268 |
| 10 No Fertilizer | None | 8 | 140 | 368 | 418 | 386 | | | | | 6.2 | | 16 | " | 16 |
| 11 | 147 | 8 | 3 | 56 | 361 | 336 | 2 | 12 | 66 | 67 | 9.7 | | 217 | " | 217 |
| 11 No Fertilizer | None | 8 | 179 | 484 | 544 | 501 | | | | | 6.3 | | 24 | " | 24 |
| 12 | 215 | 8 | 78 | 171 | 291 | 266 | 64 | 44 | 69 | 67 | 9.3 | | 308 | " | 308 |
| 12 No Fertilizer | None | 8 | 121 | 385 | 422 | 398 | | | | | 7.3 | | 37 | " | 37 |
| 13 | 224 | 8 | 18 | 51 | 236 | 202 | 7 | 10 | 43 | 40 | 10.6 | | 361 | " | 361 |
| 13 No Fertilizer | None | 8 | 252 | 522 | 553 | 510 | | | | | 7.4 | | 23 | " | 23 |
| 14 | 251 | 8 | 5 | 13 | 148 | 139 | 2 | 3 | 28 | 28 | 10.4 | | 532 | " | 532 |
| 14 No Fertilizer | None | 8 | 218 | 508 | 533 | 492 | | | | | 7.5 | | 27 | " | 27 |
| 15 | 274 | 8 | 6 | 26 | 218 | 194 | 5 | 5 | 40 | 39 | 12.3 | | 410 | " | 410 |
| 15 No Fertilizer | None | 8 | 126 | 475 | 539 | 493 | | | | | 7.1 | | 24 | " | 24 |
| 16 | 233 | 8 | 9 | 19 | 61 | 61 | 4 | 4 | 12 | 12 | 11.7 | | 245 | " | 245 |
| 16 No Fertilizer | None | 8 | 216 | 493 | 528 | 499 | | | | | 7.2 | | 20 | " | 20 |
| 19 | 255 | 16 | 0 | 6 | 50 | 62 | 0 | 1 | 10 | 14 | 11.7 | | 274 | " | 274 |
| 19 No Fertilizer | None | 16 | 329 | 516 | 503 | 457 | | | | | 7.9 | | 35 | " | 35 |
| 20 | 233 | 16 | 33 | 101 | 95 | 87 | 80 | 92 | 83 | 90 | 11.9 | | 219 | " | 219 |
| 20 No Fertilizer | None | 16 | 41 | 110 | 114 | 97 | | | | | 7.6 | | 24 | " | 24 |

a/ Dead plants were not counted b/ No plants above ground c/ Serves as a check for irregular distribution of fertilizer d/ No observations made due to misunderstanding by subordinate

pared in a manner similar to that used for the simple distributors but the seed and fertilizer were deposited simultaneously.

Both oil mill delinted and acid delinted cotton seed were planted, but all seed used in any one planting was from the same lot.

The seeds were planted at a depth of 1 inch, and by machine, except in Test 6 and 7 where a furrow was opened with a hoe and the seed carefully planted by hand 1 inch apart which is at the rate of approximately 1 bushel per acre. Accurate spacing of the seed was made possible by laying a chain with 1-inch links in the furrow. This hand seeding was more uniform and accurate than machine seeding.

In every test except No. 5 the seed was planted on the same day or the day following the application of the fertilizer. In the case of planting No. 5, twenty-three days elapsed between the application of the fertilizer and the seeding.

The moisture content of the soil at each planting was determined in duplicate on composite samples. These values are given in Tables XI, XII and XIII, with other data for easy comparison with germination counts. Rainfall was determined each day at 8:00 a.m. for the previous 24 hours with a standard rain gage; these data are presented in Table X.

Two 36-foot sections of each row were staked off after planting for later records on germination, plant growth, bloom and yield. Thus one test of each machine for either fertilizer consisted of four 36-foot rows at different points in the field. Twenty feet at each end of the row and 12.5 feet in the center were used for study of placement and any other observations that might require the disturbance of the plants or seed.

## RESULTS

Of the total of eight plantings four were made at the Sand Hill Experiment Station prior to April 20 but were destroyed by a sand storm on May 2, at which time more or less data had been collected on germination. Since complete data are not available on these four plantings they are omitted from this report.

Numerical data are not presented for the fifth planting since only a negligible amount of cotton was produced. Inasmuch as the fertilizer was applied in coarse sand 23 days before the seed was planted, it is evident that considerable leaching had taken place.

Results on germination, growth, bloom and yield for the sixth, seventh and eighth plantings are presented in Tables XI, XII and XIII, respectively. In interpreting these results due consideration should be given to the actual rate of application, the irregularity of distribution (Table V), and the placement of the fertilizer (Fig. 3).

Plots on which the fertilizer was uniformly distributed by hand served as a check on the irregular distribution by those machines which placed the fertilizer similarly in relation to the seed. Although these checks were distributed by hand it is believed that they are comparable with machine plots, since the fertilizer was carefully applied in open furrows in each case and treated similarly thereafter.

**Germination.** The number of seedlings, growing on each plot were counted as soon as practicable after they began to appear and at regular intervals for several weeks thereafter or until new plants ceased to appear.

Practically all the plots to which fertilizer was applied in the sixth planting on Norfolk sand showed decided evidence of delayed germination. (See Table XI). Rows

TABLE XII. Effect of fertilizer, as applied by various types of machines, on cotton planted May 14, 1929 in Cecil Sandy Clay Loam containing 15.47% moisture.

| Machine Number | Application Rate | Number of Replications | Germination as indicated by seedlings appearing above the ground: Average number per plot (36-ft row) | | | Germination: Ratio of fertilized to unfertilized | | | Average Length of Plants | Number of Blooms per plot | Average yield of seed cotton | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 14 | | May 21 | May 31 | June 6 [a] | May 21 | May 31 | June 6 [a] | July 3 | July 26 to Aug. 10 inc. | Oct. 14 | Nov. 6 | Total |
| | Lbs. per acre | | | | | Per cent | Per cent | Per cent | Inches | | Lbs. per acre | Lbs. per acre | Lbs. per acre |
| **Seed and 4-8-4 fertilizer planted in separate operations** | | | | | | | | | | | | | |
| 1 | 636 | 4 | 311 | 315 | 306 | 100 | 103 | 98 | 16.8 | 172 | 773 | 111 | 884 |
| 2 | 800 | 4 | 316 | 342 | 347 | 102 | 112 | 111 | 15.4 | 186 | 763 | 109 | 872 |
| 4 | 962 | 4 | 305 | 310 | 315 | 98 | 102 | 101 | 15.0 | 187 | 914 | 89 | 1003 |
| 5 | 836 | 4 | 309 | 295 | 298 | 99 | 97 | 95 | 14.6 | 188 | 841 | 145 | 986 |
| 6 | 818 | 4 | 303 | 306 | 308 | 97 | 100 | 99 | 15.2 | 183 | 739 | 110 | 849 |
| 7 | 796 | 4 | 333 | 317 | 327 | 107 | 104 | 105 | 15.7 | 184 | 758 | 70 | 828 |
| 8 | 750 | 4 | 321 | 321 | 331 | 103 | 105 | 106 | 14.4 | 196 | 846 | 94 | 940 |
| Uniform Hand Distribution [b] | 800 | 2 | 306 | 289 | 287 | 98 | 95 | 92 | 17.8 | 235 | 940 | 53 | 993 |
| No fertilizer | None | 10 | 311 | 305 | 312 | | | | 11.5 | 106 | 493 | 101 | 594 |
| **Seed and 12-24-12 fertilizer planted in separate operations** | | | | | | | | | | | | | |
| 1 | 303 | 4 | 320 | 324 | 345 | 102 | 95 | 101 | 13.7 | 184 | 1077 | 179 | 1256 |
| 2 | 249 | 4 | 322 | 308 | 319 | 102 | 90 | 93 | 14.1 | 181 | 929 | 142 | 1071 |
| 3 | 230 | 4 | 307 | 307 | 327 | 98 | 90 | 96 | 14.3 | 195 | 953 | 135 | 1088 |
| 4 | 255 | 4 | 305 | 307 | 326 | 97 | 90 | 96 | 13.6 | 180 | 890 | 171 | 1061 |
| 5 | 391 | 4 | 298 | 317 | 335 | 95 | 93 | 98 | 15.2 | 190 | 907 | 200 | 1107 |
| 6 | 238 | 4 | 298 | 319 | 329 | 95 | 94 | 96 | 15.8 | 165 | 839 | 132 | 971 |
| 7 | 320 | 4 | 307 | 287 | 305 | 98 | 84 | 89 | 13.4 | 163 | 772 | 149 | 921 |
| 8 | 205 | 4 | 315 | 297 | 327 | 100 | 87 | 96 | 14.8 | 143 | 726 | 163 | 889 |
| Uniform Hand Distribution [b] | 267 | 2 | 314 | 296 | 325 | 100 | 87 | 95 | 15.9 | 197 | 1074 | 191 | 1265 |
| No fertilizer | None | 10 | 314 | 340 | 341 | | | | 11.1 | 94 | 508 | 173 | 681 |
| **Seed and 12-24-12 fertilizer planted in one operation** | | | | | | | | | | | | | |
| 10 | 234 | 4 | 389 | 426 | 431 | 82 | 80 | 83 | 11.9 | 187 | 804 | 175 | 979 |
| 10 No fertilizer | None | 4 | 476 | 530 | 521 | | | | 9.1 | 76 | 414 | 205 | 619 |
| 11 | 190 | 4 | 325 | 393 | 427 | 58 | 65 | 71 | 13.0 | 165 | 811 | 174 | 985 |
| 11 No fertilizer | None | 4 | 558 | 601 | 599 | | | | 8.0 | 96 | 420 | 194 | 614 |
| 12 | 250 | 4 | 157 | 232 | 229 | 41 | 49 | 48 | 15.6 | 177 | 905 | 156 | 1061 |
| 12 No fertilizer | None | 4 | 382 | 475 | 472 | | | | 10.2 | 79 | 353 | 170 | 523 |
| 13 | 247 | 4 | 163 | 284 | 329 | 43 | 53 | 61 | 12.8 | 225 | 1050 | 158 | 1208 |
| 13 No fertilizer | None | 4 | 380 | 538 | 542 | | | | 10.5 | 71 | 335 | 145 | 480 |
| 15 | 188 | 4 | 221 | 269 | 296 | 37 | 40 | 44 | 13.5 | 187 | 1034 | 114 | 1148 |
| 15 No fertilizer | None | 4 | 598 | 665 | 663 | | | | 9.9 | 74 | 668 | 354 | 1022 |
| 16 | 172 | 4 | 49 | 81 | 123 | 8 | 11 | 17 | 12.9 | 159 | 865 | 124 | 989 |
| 16 No fertilizer | None | 4 | 625 | 721 | 724 | | | | 10.3 | 176 | 516 | 215 | 731 |

a/ Dead plants were not counted

b/ Serves as a check for irregular distribution of fertilizer

fertilized by Machines 9 and 20, which mixed the fertilizer and soil pretty thoroughly and placed very little fertilizer in close proximity to the seed, showed little delay in germination. In the case of Machine 9 little delay in germination probably was due in part to the fact that this machine was capable of applying only 120 pounds of fertilizer per acre. Plots fertilized by Machine 2 contained a relatively large number of seedlings, but these plants were very irregularly spaced when they first appeared above ground and clearly showed the effects of uneven distribution of fertilizer characteristic of this machine. At points corresponding to low delivery of fertilizer practically as many plants were counted in one foot of row as occurred in one-foot intervals on the check plots, while at points of high delivery no seedlings had appeared at the time of the first counts. Where the fertilizer was neither concentrated near nor in contact with the seed, the delay in appearance of plants above the ground was not serious since in every such case in this test there were good stands of plants three weeks after planting.

The seed on the plots where the combination machines were used, germinated several days earlier than did that on the simple-distributor plots where it wa planted by hand. This difference was due in large measure to the packing of the soil about the machine-planted seed which permitted moisture to reach the seed immediately, whereas the hand-planted seed lay in a comparatively dry soil for several days during a period of little rainfall. However, the final percentage germination for the combination machines was much lower in most cases. This apparent injury can be definitely correlated with the nearness of the fertilizer to the seed, being greatest in the cases of Machines 14, 16 and 19 which placed the fertilizer in contact with the seed, and highly significant with other machines placing the fertilizer close to the seed. The final counts, however, showed fair stands of plants on all plots except those fertilized by Machines 16 and 19.

In either planting in the Cecil sandy clay loam no significant differences in germination occurred where the fertilizer was applied by the simple distributors. When the seed and fertilizer were planted simultaneously by combination machines, the percentage germination was poorer just as in the Norfolk sand, and the lowest percentage germination in both the seventh and eighth tests were those of plots fertilized by Machines 14 and 16 which placed the seed and fertilizer in contact. The differences among the machines are less significant in the tests on the Cecil sandy clay loam, as compared with the Norfolk sand, due to the finer texture of the former, its higher moisture content at the time of planting, the more advanced season and the fact that rains fell immediately after planting.

**Early Growth.** After the last germination count was made the plants were thinned to one every six inches. In doing this a tape line was laid beside the row in order to secure accuracy and the superfluous plants were pulled out by hand. The lengths from topmost bud to root tip of a dozen of these plants selected at random from each plot were measured and the average figures for the four replications presented in the tables may be used as a criterion of the rate of growth. Fertilizer by whatever method applied materially increased the rate of growth over that of the unfertilized plants and especially in the case of those grown in Norfolk sand. In stimulating early growth the uniformly applied fertilizer was decidedly superior to that irregularly applied and similarly placed by machines. The plants on the hand-fertilized plots were all of about the same height while on the plots fertilized by machines the heights varied considerably. The rows fertilized by Machine 2 again plainly showed the effects of the cycles of delivery this machine gives, just as they did on the germination. This is illustrated in Fig. 4. At a rate of 280 pounds per

acre the maxima of these cycles are about 16 feet apart and the tallest plants were approximately this distance apart also. This relationship is shown in Fig. 5.

The plants fertilized by Machines 6, 7 and 12 were consistently small. This was probably due to the scattering and irregular distribution of the fertilizer.

**Bloom.** The bloom counts demonstrated that fertilizers have a marked effect on the total number of early blooms and that uniform applications produced the largest numbers. The results are not sufficiently consistent to demonstrate a superiority of any machine over the rest, but Machines 2 and 7 appear to be inferior in this respect.

**Yield.** The sixth, seventh and eighth plantings produced mature crops which were harvested in two pickings. As before stated, none of the rows in the fifth planting produced enough cotton to have significance in these tests; therefore these rows were not harvested. No difference was apparent as between the fertilized and the unfertilized rows.

Several plants were chopped out immediately beyond each end of the 36-foot sections, thus isolating and sharply defining the portions to be harvested. The cotton was picked only when it was dry and that on each plot was placed in a marked and tarred paper bag and weighed on a torsion balance set up in the field. The average of four or more replicate plots are presented in Tables XI, XII and XIII.

On the Norfolk sand the 4-8-4 fertilizer produced larger yields of seed cotton than did approximately equivalent amounts of 12-24-12 fertilizer. On the Cecil sandy clay loam, when due allowance is made for the difference in the checks, both fertilizers increased yields approximately the same amount.

Both fertilizers invariably produced largest yields where they were applied uniformly. An apparent exception to this in the seventh planting is due to an excess of 162 pounds of fertilizer per acre over the desired rate. Machines 1, 2 and 4 placed the fertilizer similarly to the hand distribution, but while Machines 1 and 4 distributed it fairly regularly, Machine 2 distributed the fertilizer very irregularly. The yields of plots fertilized by Machines 1 and 4 were much superior to those fertilized by Machine 2. It appears that more uniform distribution of fertilizers would increase the yields of cotton now being obtained in this country, since in these tests with both ordinary and concentrated fertilizers, with both sand and loam soils, and under different climatic conditions, uniform distribution by hand was superior to the more or less irregular machine distribution, when the fertilizer was applied at the same rate and in the same position relative to the seed.

Relatively poorest yields were obtained from plots fertilized by Machines 2, 6, 7, 14, 16, 20 and 23. Doubtless the decreased yields are not due to the same causes in every case. The only apparent difference in distribution between Machine 2 and the hand applications was that the former involved delivery cycles of large amplitude. On the other hand, the use of Machines 6, 7 and 20 resulted in poorer crops than those where No. 2 was used, and while these machines had pronounced irregularities in their delivery, they were much less marked than in the case of Machine 2. These three machines mixed the fertilizer with soil through a comparatively wide area, and wherever this occurred the yield was lower than where the fertilizer was concentrated in a narrow band, other conditions being equal. It is not clear whether this is due to too much mixing of the soil and fertilizer or the latter being too far from the seed or both. Where the fertilizer was in contact with the seed, as on plots fertilized by Machines 14 and 16, the stands of plants were poor due to the large number of seed that failed to germinate, leaving gaps in the rows. Such seed as grew on these plots produced very vigorous plants which yielded more cotton per plant than those on other plots, and thus in the case of Machine 14 in the sixth planting, this increased yield per plant more than compensated for the better stands of plants on other nearby plots. Machine 23 was adjusted to place the fertilizer 3 to 3½ inches below the seed and this appears to be too far for best results. In supplementary tests with Machine 15 placing the fertilizer at approximately 1, 2 and 3 inches below the seed slightly higher yields were obtained for the 2-inch depth than for depths of 1 or 3 inches. Thus these tests also seemed to indicate that the fertilizer should be close to but not in contact with the seed.

The fertilizer mixtures separated to a certain extent into their components during distribution. This also probably had some effect on the yield.

Thus it appears that under the conditions of these tests irregular distribution, the placement of fertilizer in direct contact with the seed or too far from the seed, and segregation of the fertilizer mixture, all contribute to a reduction of yields of cotton, but it is impossible from the data available to determine what proportion of the effect on yield was due to each of these causes. This will be studied further during the coming season.

## SUMMARY

Irregular distribution of fertilizer is caused by variable wheel slippage, cycles of delivery, lack of refinement of the distributing mechanism, changes in the depth of fertilizer in the hopper, tilting of the machine, and inability of the fertilizer to flow uniformly.

Fig. 4. Uneven plant growth resulting from irregular distribution of fertilizer

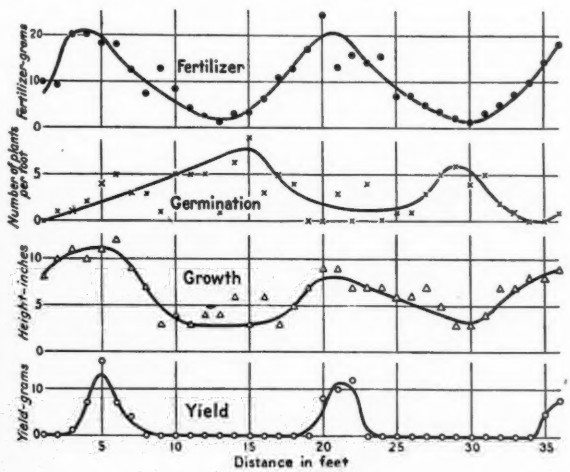



Fig. 5. Effect of irregular distribution of the 4-8-4 fertilizer applied by Machine 2 at an average rate of 280 pounds per acre on (1) germination 11 days after planting, (2) height of plants 63 days after planting, and (3) yield from unthinned plants

TABLE XIII. Effect of fertilizer, as applied by various types of machines, on cotton planted May 24, 1929 in Cecil sandy clay loam containing 11.60% moisture.

| Machine Number | Application Rate, May 24 (Lbs. per acre) | Number of Replications | Germination: Average number per plot (36-ft row), May 31 | Average number per plot, June 7 | Average number per plot, June 12 a/ | Ratio of fertilized to unfertilized, May 31 (Per cent) | Ratio, June 7 (Per cent) | Ratio, June 12 a/ (Per cent) | Average Length of Plants, July 3 (Inches) | Number of Blooms per plot, July 26 to Aug. 10 inc. | Yields of seed cotton, Oct. 14 (Lbs. per acre) | Yields, Nov. 6 (Lbs. per acre) | Total (Lbs. per acre) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seed and 4-8-4 fertilizer planted in separate operations | | | | | | | | | | | | | |
| 1 | 683 | 4 | 313 | 419 | 419 | 116 | 100 | 101 | 12.7 | 190 | 865 | 205 | 1070 |
| 2 | 692 | 4 | 272 | 396 | 402 | 100 | 94 | 97 | 11.6 | 180 | 805 | 162 | 967 |
| 4 | 727 | 4 | 272 | 375 | 378 | 100 | 89 | 91 | 12.3 | 196 | 875 | 218 | 1093 |
| 5 | 708 | 4 | 278 | 413 | 419 | 103 | 98 | 101 | 11.5 | 155 | 833 | 269 | 1102 |
| 6 | 739 | 4 | 304 | 435 | 441 | 112 | 103 | 106 | 12.3 | 191 | 845 | 241 | 1086 |
| 7 | 770 | 4 | 298 | 444 | 446 | 110 | 106 | 107 | 11.1 | 161 | 718 | 278 | 996 |
| 8 | 727 | 4 | 271 | 370 | 372 | 100 | 88 | 89 | 11.6 | 182 | 862 | 275 | 1137 |
| Uniform Hand Distribution b/ | 800 | 2 | 272 | 365 | 332 | 100 | 87 | 80 | 15.1 | 222 | 1047 | 208 | 1255 |
| No fertilizer | None | 10 | 270 | 420 | 415 | | | | 10.1 | 42 | 247 | 248 | 495 |
| 22 | 834 | 18 | 318 | 438 | 437 | 80 | 90 | 90 | 10.9 | 200 | 785 | 278 | 1063 |
| 22 No fertilizer | None | 4 | 396 | 489 | 488 | | | | 8.4 | 16 | 139 | 161 | 300 |
| Seed and 4-8-4 fertilizer planted in one operation | | | | | | | | | | | | | |
| 23 | 800 | 24 | 41 | 94 | 93 | 82 | 92 | 92 | 14.0 | 127 | 687 | 224 | 911 |
| 23 No fertilizer | None | 16 | 50 | 102 | 101 | | | | 12.6 | 67 | 368 | 201 | 569 |
| Seed and 12-24-12 fertilizer planted in separate operations | | | | | | | | | | | | | |
| 1 | 287 | 4 | 289 | 383 | 376 | 103 | 96 | 98 | 12.5 | 132 | 685 | 258 | 943 |
| 2 | 230 | 4 | 274 | 398 | 397 | 98 | 100 | 104 | 12.0 | 105 | 475 | 199 | 674 |
| 3 | 270 | 4 | 277 | 392 | 398 | 99 | 98 | 104 | 10.8 | 129 | 670 | 239 | 909 |
| 4 | 304 | 4 | 277 | 377 | 379 | 99 | 94 | 99 | 11.5 | 146 | 740 | 236 | 976 |
| 5 | 355 | 4 | 249 | 378 | 375 | 89 | 95 | 98 | 12.5 | 113 | 598 | 284 | 882 |
| 6 | 255 | 4 | 267 | 399 | 390 | 95 | 100 | 102 | 10.9 | 127 | 623 | 241 | 864 |
| 7 | 303 | 4 | 253 | 349 | 362 | 90 | 87 | 94 | 11.8 | 102 | 560 | 268 | 828 |
| 8 | 236 | 4 | 218 | 356 | 343 | 78 | 89 | 89 | 11.8 | 47 | 588 | 255 | 840 |
| Uniform Hand Distribution b/ | 267 | 2 | 277 | 374 | 367 | 99 | 94 | 96 | 11.2 | 156 | 866 | 227 | 1093 |
| No fertilizer | None | 12 | 280 | 399 | 382 | | | | 10.2 | 31 | 92 | 205 | 297 |
| Seed and 12-24-12 fertilizer planted in one operation | | | | | | | | | | | | | |
| 10 | 331 | 4 | 124 | 193 | 188 | 37 | 46 | 46 | 11.9 | 194 | 1082 | 376 | 1458 |
| 10 No fertilizer | None | 4 | 337 | 423 | 409 | | | | 8.3 | 60 | 330 | 295 | 625 |
| 11 | 136 | 4 | 223 | 416 | 388 | 54 | 77 | 77 | 10.6 | 154 | 715 | 280 | 995 |
| 11 No fertilizer | None | 4 | 414 | 538 | 502 | | | | 9.3 | 45 | 298 | 325 | 623 |
| 12 | 229 | 4 | 188 | 325 | 304 | 42 | 58 | 56 | 10.9 | 146 | 751 | 285 | 1036 |
| 12 No fertilizer | None | 4 | 448 | 562 | 547 | | | | 9.0 | 36 | 244 | 291 | 535 |
| 13 | 293 | 4 | 132 | 252 | 241 | 35 | 49 | 47 | 10.7 | 151 | 838 | 414 | 1252 |
| 13 No fertilizer | None | 4 | 379 | 518 | 511 | | | | 8.7 | 35 | 231 | 270 | 501 |
| 14 | 300 | 4 | 16 | 48 | 51 | 5 | 10 | 11 | 11.3 | 98 | 565 | 356 | 921 |
| 14 No fertilizer | None | 4 | 332 | 458 | 446 | | | | 10.4 | 60 | 289 | 317 | 606 |
| 15 | 274 | 4 | 85 | 137 | 134 | 38 | 47 | 49 | 9.5 | 151 | 728 | 306 | 1034 |
| 15 No fertilizer | None | 4 | 224 | 290 | 275 | | | | 10.3 | 50 | 347 | 293 | 640 |
| 16 | 184 | 4 | 48 | 100 | 93 | 18 | 28 | 27 | 8.6 | 125 | 664 | 292 | 956 |
| 16 No fertilizer | None | 4 | 267 | 362 | 350 | | | | 8.3 | 66 | 363 | 353 | 716 |

a/ Dead plants were not counted   b/ Serves as a check for irregular distribution of fertilizer

Segregation of fertilizer components occurs to a greater or less extent in all machines.

Some factors contributing to ease of operation of the machines are (1) light weight and compact construction of walking machines, (2) adequate hopper capacity, (3) easy accessibility for cleaning, and (4) convenient adjustments for delivery rate.

It is either difficult or impossible to adjust a majority of the machines reasonably close to the rates desired.

Combination machines as a class will not deliver fertilizers of the usual grade at a rate frequently used in the southeastern states.

Uniform depth of planting is possible only when the furrow opener with an effective depth gage is free to follow the surface of the seedbed.

Under the conditions of this study fertilizer is most efficient when uniformly applied relatively close to the seed but not in contact with it.

(AUTHORS' NOTE: The authors are deeply indebted to H. R. Smalley, representing the Joint Committee on Fertilizer Application, for his assistance in the organization and administration of the project, and to J. A. Riley and J. E. Adams of the Sand Hill Experiment Station, and C. S. Patrick, D. W. Teare and T. S. Buie, of Clemson College, South Carolina, for assistance in connection with the field and laboratory work. The authors also wish to express their appreciation for the cooperation of manufacturers in furnishing machines for the tests.)

# Studying Farm Costs

A MAN who has as much invested in good dairy cows, good farm tools, and in working capital as the land itself, will make a go of farming, the late Governor Hoard of Wisconsin is reported to have once advised. While Danish farmers do not carry out the Hoard formula they do have a relatively larger amount invested in livestock and machinery per acre than the average American farmer, according to an interesting statement issued recently by the Danish Bureau of Farm Management. Two hundred farms, around 70 acres in size, carried a livestock investment of $40 per acre and a machinery investment of nearly $20 per acre. These farms each sold about $6,000 worth of products in 1928 returning a net income of $1,100.

In 1925, the average investment per acre in farm equipment in the United States was only $7.15. Eastern states with their smaller farms generally showed the greatest investment, Massachusetts leading with $21.30 per acre. Wisconsin not only led in development of the dairy industry, but also had the greatest investment in farm equipment with $13.40 per acre. Iowa was credited with $10.80 per acre while Michigan, Illinois and Minnesota all had an investment of more than $8.00 per acre.

Farmers justify their purchase of new machinery to utilize their labor to greater advantage and increase the size of their farm business. Taxes, rent and insurance are all fixed charges, but the individual farmer does have control over power and labor, which are major items in farm costs and also a determining factor in size of farm business, and likewise net income.

There are many farms where more power would do the work in a shorter time and enable the operator to increase the size of his business. Perhaps the available power is not being used as efficiently as might be possible with a change in crop rotation or through the use of a new tool. Each farm annually presents this problem which is somewhat simplified if a complete set of records are available. When an analysis of the farm enterprise is being made a "written memorandum is worth a carload of recollections."

# Laboratory Studies on Toxic Chemical Control of Wood Destroying Fungi[1]

By Harold T. Barr[2]

DURING the past seven years a study has been made at the Arkansas Agricultural Experiment Station of the durability of fence-post materials. The first records were service tests in which the resistance to decay and termites was studied. The life of steel posts under field conditions is also included in this work.

Three years ago a large number of uniform pine and oak specimens were treated with creosote, zinc chloride, sodium fluoride, borax, sulphur, refuse cylinder oil, lime-sulphur spray and lubricating-oil emulsion spray. Two years after setting the checks showed damage of 33 per cent and complete failure of 7.7 per cent. The treated specimens showed no or very slight damage.

[1]Paper presented at a joint meeting of the Southern and Southwest Sections of the American Society of Agricultural Engineers at Houston, Texas, February, 1929. Also Research Paper No. 135, Journal Series, University of Arkansas.

[2]Instructor in agricultural engineering, University of Arkansas. Assoc. Mem. A.S.A.E.

In the past year, to supplement the field work, a laboratory study of the effectiveness of some wood preservatives on certain wood-destroying organisms was undertaken.

A chemical for use in preserving wood must be highly toxic to wood-destroying organisms, permanent, inexpensive, obtainable in large quantities, and easily handled. Some chemicals are very toxic to fungi, yet their effect is of such short duration that they are uneconomical as preservatives. If these same chemicals could be converted to less soluble compounds to prevent leaching, and at the same time maintain their toxic values, they would be very desirable.

Because of its toxic value and ready availability copper was chosen for use in the experimental work. Copper salts form with certain other chemicals, precipitates which are less soluble in water, but none the less toxic when a small amount of acid is present. Dr. Curtin[3] has shown

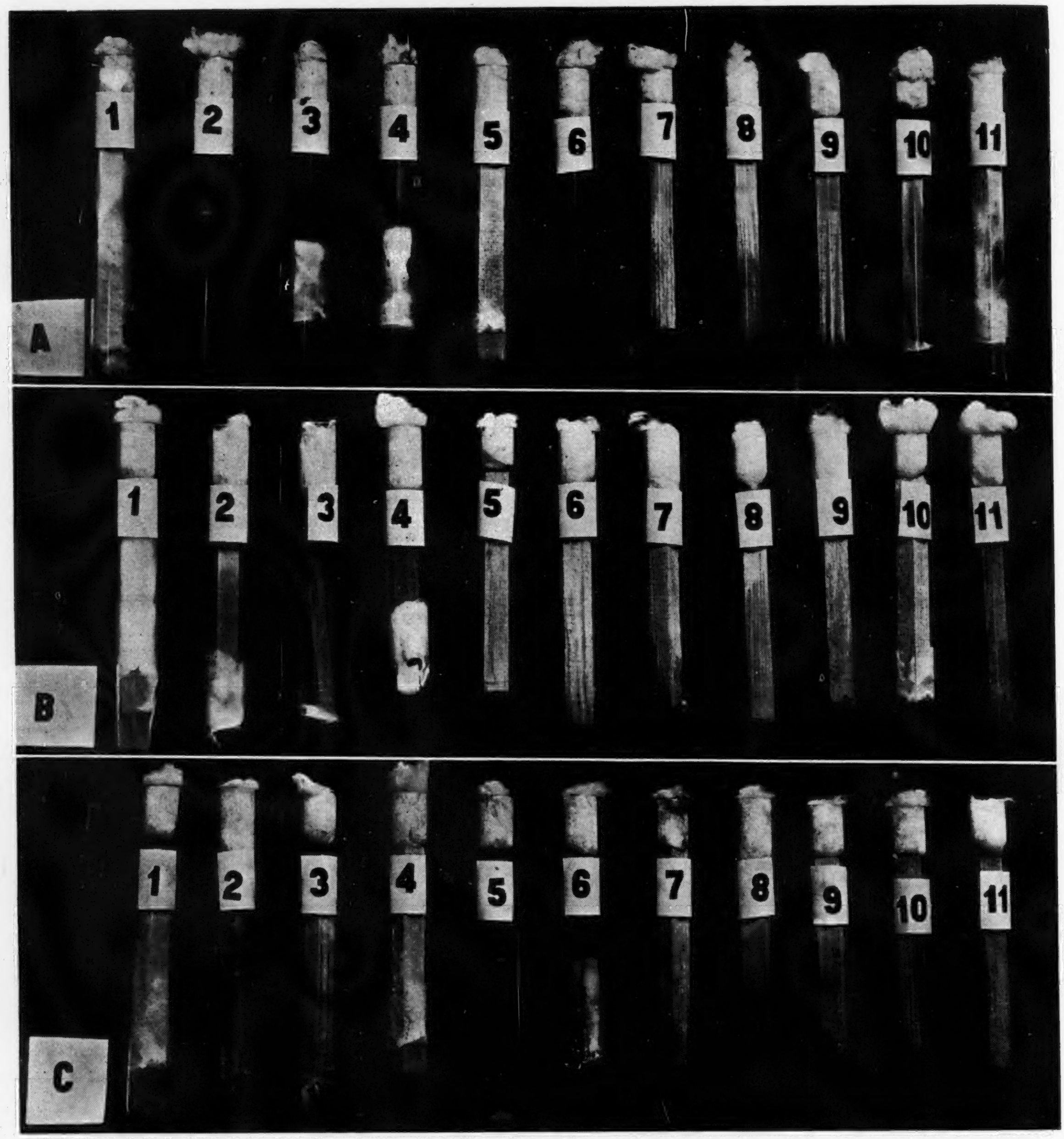
[3]Chemist, Western Union Telegraph Co.

RESULTS OF LABORATORY TESTS OF WOOD PRESERVATIVE TREATMENTS

| Preservative | Treatment | FOMES ANNOSUS | | | LENTINUS LEPIDUS | | | LENZITES SEPIARIA | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Feeble growth in media | Amount of growth | Dead | Feeble growth in media | Amount of growth | Dead | Feeble growth in media | Amount of growth | Dead |
| Zinc Chloride | Without leaching | | 0.7 | X | X | | | | 0.1 | X |
| | Boiled 2 hours | | 2.5 | | X | | | | | |
| Sodium Fluoride | Without leaching | X | | X | X | | X | X | | X |
| | Boiled 2 hours | | 0.2 | X | | 0.3 | X | | 7.5 | |
| Copper Borate | Without leaching | X | | X | | | X | | | X |
| | Boiled 2 hours | X | | X | | | X | X | | X |
| Copper Arsenite | Without leaching | X | | X | | | X | | | X |
| | Boiled 2 hours | X | | X | | | X | | | X |
| Copper Aceto Arsenite | Without leaching | | | X | X | | X | X | | X |
| | Boiled 2 hours | X | | X | | | X | | | X |
| Sulphur | Without leaching | | 0.9 | | | 0.4 | | | 0.2 | |
| | Boiled 2 hours | | 1.0 | | | | | | | |
| Refuse Cylinder Oil | Without leaching | | 2.5 | | | 1.9 | | | 2.6 | |
| | Boiled 2 hours | | 1.6 | | | 1.4 | | | 3.6 | |
| Creosote | Without leaching | | | X | | | X | | | X |
| | Boiled 2 hours | | | X | | | X | | | X |
| Commercial* | Without leaching | | 0.3 | X | | 0.1 | | | 0.4 | X |
| | Boiled 2 hours | | | | | | | | | |
| Untreated** | As cut from the log | | 4.0 | | | 2.3 | | | 2.0 | |
| | Boiled 2 hours | | 3.7 | | | 3.0 | | | 3.2 | |

*This is a new commercial preservative, which was used with pressure treatments.

**The growth as given is for 25 days, before 50 days all checks had been completely covered with a heavy growth of fungi.




A. Fomes Annosus after 25 days incubation. (1) Untreated, 3.6 in. growth; (2) creosote, no growth when not leached; (3) refuse cylinder oil, 1.5 in. growth when not leached; (4) refuse cylinder oil, 1.9 in. boiled two hours; (5) sulphur, 0.5 in. growth when boiled two hours; (6) commercial, no growth when not leached; (7) copper aceto arsenite, no growth when boiled two hours; (8) copper arsenite, no growth, boiled two hours; (9) copper borate, no growth, boiled two hours; (10) sodium fluoride, 0.2 in. growth, boiled two hours; (11) zinc chloride, 2.5 in. growth, boiled two hours

B. Lentinus Lepidus after 25 days incubation: (1) Untreated, 3.0 in. growth; (2) commercial, 1.1 in. growth—inside section; (3) commercial, 0.1 in. growth—outside section; (4) refuse cylinder oil, 1.0 in. growth when not leached; (5) copper aceto arsenite, no growth—boiled two hours; (6) copper arsenite, no growth—when not leached; (7) copper borate, no growth—boiled two hours; (8) sodium fluoride, no growth—when not leached; (9) zinc chloride, no growth—when not leached; (10) sulphur, 0.4 in. growth—on wood higher in tube; (11) creosote, no growth

C. Lenzites Sepiaria after 25 days incubation: (1) Untreated, 2.3 in. growth; (2) commercial, 0.4 in. feeble growth outside section; (3) commercial, 1.0 in. feeble growth inside section; (4) sulphur, 0.5 in. growth on wood—1.0 in. high in tube; (5) creosote, no growth when not leached; (6) refuse cylinder oil, 2.0 in. growth when not leached; (7) zinc chloride, no growth when not leached; (8) sodium fluoride, no growth when not leached; (9) copper arsenite, no growth, boiled two hours; (10) copper borate, no growth, boiled two hours; (11) copper aceto arsenite, no growth, boiled two hours

that seventeen fungi of importance as wood-destroyers liberate in their growth a weak acid of from pH 5 to pH 3. Hence, a more permanent poison, yet one which is slightly soluble in an acid of from pH 5 to pH 3, would seem desirable for wood treatment.

Precipitates were formed from arsenious oxide and copper acetate, arsenious oxide and copper sulphate, and sodium tetraborate (borax) and copper sulphate, each pre-

cipitate being dried out before testing for solubility.

In distilled water they were each found insoluble; but in an acid of pH 4 to pH 3.5, gave a reaction showing the liberation of some copper in the solution.

To secure uniform test pieces a large post of shortleaf Southern yellow pine was cut into pieces $\frac{3}{8}$x$\frac{3}{8}$x4 inches, all pieces containing knots or heart wood being thrown out. A treatment of 45 minutes at 180 degrees (Fahrenheit), plus a cold treatment of 4 hours at 70 degrees, was used in all cases except that of molten sulphur. In treatments where copper was used the arsenious oxide or sodium tetraborate was heated and the copper acetate or copper sulphate used in a bath of 70 degrees. As the copper came into contact with the arsenious oxide or sodium tetraborate a precipitate was formed in the wood. These precipitates, as previously stated, are not soluble in water, but are soluble in weak acids.

The following preservatives in the amounts indicated were used:

| | |
|---|---|
| Copper aceto arsenite | 1.28 lb. dry chemical per cu. ft. of wood |
| Copper arsenite | 1.50 lb. dry chemical per cu. ft. of wood |
| Copper borate | 1.42 lb. dry chemical per cu. ft. of wood |
| Zinc chloride | 1.41 lb. dry chemical per cu. ft. of wood |
| Sodium fluoride | 1.26 lb. dry chemical per cu. ft. of wood |
| New commercial preservative | Unknown |
| Sulphur | 27.5 lb. dry chemical per cu. ft. of wood |
| Creosote | 30.0 lb. of liquid per cu. ft. of wood |
| Refuse cylinder oil | 26.2 lb. of liquid per cu. ft. of wood |

To obtain in a short period of time an effect approaching that of leaching for considerable time in the field, six pieces of each treatment were boiled in 600 grams of distilled water for one hour, removed, rinsed in 200 grams distilled water and boiled in 600 grams of distilled water for another hour. A second six pieces of each treatment were soaked for 48 hours in distilled water and then removed for 48 hours, this alternate soaking and drying being maintained for three months.

After exposure to the air in the laboratory for one week each set of treated pieces was sterilized with steam under 15 pounds pressure for 30 minutes.

A quantity of nutrient medium composed of 1.5 per cent agar and 2.5 per cent malt syrup was prepared and placed in $\frac{5}{8}$x6-inch test tubes so there was about one inch of medium in each tube. These were then plugged with cotton and sterilized in the same manner as the treated test pieces.

Pure cultures of Fomes Annosus, Lentinus Lepideus, and Lenzites Sepiaria were used to inoculate the sterilized test tubes. Each fungus series was kept separate. The sterilized pieces of wood were then placed in the inoculated tubes and put in the incubator. For each treatment two pieces of wood as treated, two which had been boiled, two which received the alternated wet and dry treatment and two checks were used for each of the three fungi. At periods of 4, 25 and 50 days after inoculation the material was examined and measurements of the growth taken, as shown in the accompanying table, which shows results at the end of the 50-day period.

In some cases the fungi which were growing at 25 days (when photographed), had been killed by the poison at 50 days as shown by the table.

SUMMARY

Some chemicals not soluble in water are toxic to certain wood destroying organisms. The copper compounds used can be precipitated out in the wood. Copper borate shows promise as a wood preservative because of its toxic value, permanancy and relatively low cost. Refuse cylinder oil has very little retarding effect upon the growth of fungi, and does not prevent their growth. The specimens given the commercial treatment resisted leaching to a high degree and prevented growth of fungi.

# Wider Opportunities for Engineers

FOR after all, before we were engineers we were men, and before we were members of an engineering society we were citizens. More important still, if our training and talents and our professional organizations give us special or superior knowledge, they also lay on us an obligation to use them in the public welfare. Thus the Society, through its group activities and through the influence of its individual members, will find one of its greatest duties in stimulating civic and social service, and a sense of the obligations of citizenship.

The time has come when a realization of purpose should transcend an interest in technique. The technological achievements of the past have been typical of the times in which they were accomplished. It was an age of invention and mechanization which achieved unbelievable results in the material progress of the human race. Further progress along similar lines seems to be secure. With our greater knowledge in many realms it is possible that still more spectacular advances may be typical in the future. But great as these may be, it is essential that we progress socially. The public appreciation of material progress is becoming jaded. There is evidence at hand that the native concern for the mechanistic novelties we have evolved is to be replaced by a better-proportioned sense of their place in human affairs. Thus our engineering achievements, becoming more matter of fact, will be viewed more properly as means to a desirable end, and not in themselves a goal of first-rate significance. When this day arrives, engineers will have developed a new sense of responsibility to society, and engineering organizations will undertake the solution of innumerable problems that have been the unfortunate and often tragic concomitants of technological progress. After all, be we engineers, lawyers, or physicans, it is life itself and its satisfactions that are important, and not the fascinating details of its technique.

Toward this large view of intellectual and spiritual developments an engineering society must look in the near future if it is to be adequately representative of the best to which its members, individually and collectively, may aspire. Then its members will be sought for in the councils of governments, local and national, and will be leaders in the communities where they reside, guardians alike of its material welfare and its culture.

The process by which this desirable condition may be achieved is that of education for the engineer, and sympathetic interpretation of him and his social and civic function to the world at large and its leaders. To supply the member with better and more adequate aids to his professional career is a proper function for an engineering society. To conduct its activities so that their influences on civilization will be for its welfare is still more its function. . . . . . — Calvin W. Rice in "Mechanical Engineering," Vol. 52, No. 4, April, 1930.

## Let Us Have Safety First

Editor AGRICULTURAL ENGINEERING:

SAFETY for the operator must be one of the first conditions to meet in designing any piece of equipment. The infernal contrivance described as a wood splitting machine in AGRICULTURAL ENGINEERING for March 1930, page 104, can not be too strongly condemned. The list of accidents from unsafe rotating machinery is long enough without promoting equipment which will add to it.

If it is desired to use flywheels for storing energy for chopping wood, the blade should be driven from a crank and crosshead instead of being mounted on the flywheel. This will give it a definite limited stroke so that adequate safeguards may be installed to protect the operator.

R. L. PERRY.

Division of Agricultural Engineering
University of California.

# Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

**A Study of the Oil Burner as Applied to Domestic Heating,** A. H. Senner (U. S. Department of Agriculture, Technical Bulletin 109 (1929), pp. 84, pls. 2, figs. 37).—This bulletin deals with the more technical phases of the investigations reported in Department Circular 405.

The investigation of the vaporizing type of burner was restricted to a series of tests on the products of nine different manufacturers, all of which, while somewhat different in appearance, were essentially the simple casting type of burner with the hot "spreader plate" which must be previously heated by means of a wick in order to produce the initial vaporization. The tests revealed not only that the efficiency of this type of burner was somewhat lower than that of the atomizing type, but also that there was a decided tendency, in the vaporizing burner, toward the production of soot.

The operating cost, even with satisfactory conditions otherwise, is somewhat higher than that of some atomizing burners.

The combustion efficiencies of the several representative atomizing burners tested were substantially the same. Ten per cent $CO_2$ in the flue gases was quite easily attained by the various burners, and, in fact, operation at this air-fuel ratio was used as a basis of comparison for the performance of the different burners, although higher percentages of $CO_2$ were obtained quite readily. As might be expected, there was some difference as to soot production, but in no case with the better atomizing burners, properly adjusted, could this difference be called significant.

The investigation as to the relative merits of the different grades of fuel revealed that the burners designed to use the heavier, cheaper fuels did so with efficiencies equal to those attained when the burners were supplied with the lighter fuels. The heavier fuels were burned with relative freedom from soot production. In intermittent operation the starting loss with the heavier fuels was quite as small as with the lighter fuels. Complete chemical and physical tests of the oils showed that the heavier oils, that is, the 28 to 32-degree distillates, should be quite satisfactory from the standpoint of viscosity, etc. There is no reason to believe that there will occur any clogging of lines with such oils under ordinary operating conditions, or any other undesirable effects which would require increased service.

The selection, for oil burning, of a boiler to supply a given radiation load is not necessarily safe if this selection is based upon similar ratings for burning coal. Aside from the possible differences in combustion characteristics of the two fuels, there is the additional fact that for intermittent operation of the oil-fired boiler, the actual instantaneous rate of heat emission is greater than for coal at the maximum.

With flat fuel rates the relative economy of oil heating, as compared with gas heating, increases with the increased size of the heating plant.

The effect of automatic control on over-all efficiency is important. With the high-low flame control of temperature, the furnace conditions as regards combustion are practically always favorable; that is, the temperature of the refractory or metallic combustion chamber is always sufficiently high to permit good catalytic effect.

With intermittent operation the conditions in the furnace may, as regards combustion, be relatively unfavorable after a long period of inactivity. However, if the temperature of the furnace walls does not fall below the critical temperature, the loss may be no greater than that which exists when equilibrium conditions are reached, that is, after the maximum temperatures have been attained.

The results of analyses of the stack gases at frequent intervals during the operation of starting showed that the $CO_2$ content for all practical considerations reaches its maximum value almost immediately and the starting loss really is in the form of unburned combustible as represented by the $H_2$, the CO, and the unsaturated hydrocarbons identified by the formula $C_n H_{2n}$.

The ordinary Orsat apparatus may not tell the whole story as to the constituents of the stack gases. This apparatus indicates the percentages of $CO_2$, $O_2$, CO, and N by difference. If a heat balance is struck, assuming that only these gases are passing up the stack, it will frequently be learned that the unaccounted-for loss may be quite high, even after due allowance is made for radiation. This difference has, from the tests reported on in this bulletin, been found to lie in heat units carried off by certain percentages of $H_2$ and $C_n H_{2n}$ illuminants, in addition to the CO. The Burrell Orsat has been employed for such analyses for the determination of these additional avenues of heat loss.

**Effects of Knock-Suppressing and Knock-Inducing Substances on the Ignition and Partial Combustion of Certain Fuels,** R. E. Schaad and C. E. Boord (Industrial and Engineering Chemists, (Washington, D. C.) 21 (1929), No. 8, pp. 756-762, figs. 20).—The results of studies conducted at Ohio State University, which were presented at the meeting of the American Chemical Society at Detroit, Michigan, in September, 1927, are reported.

Hot-wire ignition curves were determined for toluene, isoamyl acetate, and kerosene between the lower and upper limits of inflammability. The fuel-air mixtures investigated were produced by a vapor pressure method which is shown to be applicable to the continuous and reproducible preparation of such a series of mixtures. The current required by an electrically heated platinum wire for ignition of the most easily ignitible mixture of air and toluene, isoamyl acetate, or kerosene was increased by the addition to the fuel of a knock suppressor such as lead tetraethyl or selenium diethyl. On the contrary, the addition of one of the knock inducers decreased the hot-wire ignition current. The knock suppressors and inducers used had no noticeable effect on the ignition curves obtained for toluene, isoamyl acetate and kerosene by means of direct-current break sparks.

With the fuels for which vapor pressure data either were known or could be estimated, the fuel-air mixtures most easily ignited by a hot platinum wire and by direct-current break sparks had the calculated compositions required for giving combustion to carbon monoxide and to carbon dioxide, respectively.

Introduction of approximately 1.95 per cent by volume of one of the knock suppressors into liquid toluene, isoamyl acetate, or kerosene decreased the partial combustion taking place in the fuel-air mixture in the vicinity of a platinum wire heated by a current less than that required for ignition, while, on the contrary, the introduction of the same volume of a knock inducer increased this partial combustion or "pre-ignition" combustion, as it is called here, because it took place at a filament current less than that necessary for ignition.

**Low-Cutting for Harvesting Corn,** F. Irons and W. J. Parvis (U. S. Pepartment of Agriculture, Miscellaneous Publication 65 (1929), pp. 36, pl. 1, figs. 80).—Detailed descriptions are given of al low-cutting attachment for four commercial makes of corn binders and a low-cutting hand device or hoe, both developed by the Division of Agricultural Engineering of the U. S. D. A. Bureau of Public Roads.

**A Summer Shelter for New Jersey Pullets,** L. M. Black (New Jersey Station Hints to Poultrymen, 17 (1929), No. 10, pp. 4, structure are given.
figs. 3).—Working drawings and a bill of materials for this

**Fires on Farms,** H. E. Roethe (U. S. Department of Agriculture Leaflet 44 (1929), pp. 5, figs. 5).—Practical information is given on the sources of farm fires and how they may be reduced.

## Book Review

**"Abstracts of Papers to be Read at World Engineering Congress,"** is a thick paper-bound volume containing abstracts in the English language of 792 of the papers presented at the World Engineering Congress held in Tokyo, Japan, in October and November, 1929. Whether or not copies are still available, and if so, the price, is not known. Communications concerning it should be addressed to World Engineering Congress, Nihon, Kogyo Club Building, Marunouchi, Tokyo, Japan.

**"Tests on Large Timber Columns and Presentation of the Forest Products Laboratory Column Formula,"** Technical Bulletin 167 of the Forest Products Laboratory, U. S. Forest Service, presents the results of tests of a large number of Douglas fir and southern pine timber columns, 12 inches by 12 inches in cross section and from 2 to 24 feet long, in grades from clear to very knotty. These and other data are shown in their relation to column formula. The bulletin is prepared especially for engineers, architects, contractors, and others who are desirous of knowing the strength of timber columns or who are interested in the study of column formulas. When it is off the press it will be sent free to those requesting it as long as the supply lasts. Requests for copies should be addressed to the U. S. Forest Products Laboratory, Madison, Wis.

# Who's Who in Agricultural Engineering

B. B. Robb

J. K. MacKenzie

D. H. Doane

M. C. Betts

## B. B. Robb

Byron Burnett Robb (Mem. A.S.A.E.) is professor of rural engineering at Cornell University. New York State, in which he was born, has remained his center of interest and activity. As a young man he taught school for two years before entering the College of Agriculture at Cornell University in 1907. Specializing in farm mechanics, he earned his bachelor's degree in agriculture in 1911; was named as an instructor; earned his master's degree in 1913 and was advanced to the rank of assistant professor; and in 1919 was granted a professorship. During the summers from 1911 to 1915 he was employed as drainage engineer by the state department of agriculture. Land drainage is his speciality, but he now has charge of all agricultural-engineering extension work in the state and with nine assistants carries out what is probably the largest state agricultural-engineering extension program in the United States. On sabbatic leave in 1923 he studied educational methods at Harvard University. He is co-author with F. G. Behrends of a text, entitled "Farm Engineering," copyrighted in 1924. At present he is vice-chairman of the North Atlantic Section of the Society and last fall was chairman of the program committee for its meeting at Amherst.

## J. K. MacKenzie

John Kenneth MacKenzie (Assoc. Mem. A.S.A.E.) has recently joined the Caterpillar Tractor Company organization as agriculturist for western Canada. Born in Nova Scotia, Canada, where he also received his preparatory education, he went to the University of Saskatchewan to study agricultural engineering. After graduating in 1918 he remained there as agricultural engineering specialist until, in 1919, he went to the Province of Alberta to be instructor in farm mechanics in the Alberta School of Agriculture at Vermilion. From 1922 until his present change he was assistant superintendent of the Dominion Experiment Station at Swift Current, Saskatchewan. There he exercised general supervision over all the field work of the station and particularly all work dealing with farm machinery. This give him experience in research work with tillage and harvesting machinery and with the agricultural engineering problems in western Canada which furnishes an ideal background for the position he has recently accepted. The data produced by the station are accepted as authoritative throughout western Canada. At meetings of the Power and Machinery Division of the American Society of Agricultural Engineers he has reported on the work of the station with the combine.

## D. H. Doane

D. Howard Doane (Mem. A.S.A.E.), agricultural engineer and manager of Doane Agricultural Service, has been a fountain of energy concentrated on the development of farm management for the past quarter of a century. In 1906, while still an undergraduate majoring in farm management at the University of Missouri, he began work along that line with the Office of Farm Management of the U.S.D.A. For ten years following he was continuously engaged in farm management work with either, and sometimes both, the U.S.D.A. or the University of Missouri. Receiving his bachelor's degree in 1908, he remained with the University and earned his master's degree in farm management in 1909; stayed to develop and become professor and head of the first department of farm management in an agricultural college in the United States; and was made state county agent leader for Missouri in 1912. Breaking off state and federal connections in 1916, he managed farms under various arrangements until in 1922 he organized the service which now manages more than 100,000 acres in seven states. He is also active in several other agricultural and engineering organizations and listed in "Who's Who in America."

## M. C. Betts

Morris Cotgrove Betts (Mem. A.S.A.E.) is senior architect in the division of agricultural engineering, Bureau of Public Roads, U. S. Department of Agriculture, in charge of the farm structures work of the division. He graduated from the School of Architecture, University of Pennsylvania, with the class of '98; spent ten years in professional work with three leading architects in Philadelphia; joined the editorial staff of the Ladies Home Journal as architectural editor; and there came in contact with conditions in the farm structures field. His growing realization of the need of improvement in rural structures finally lead him to seek opportunity for work in this direction through government channels. Since entering government service in 1914 he has been responsible for several publications and a large number of farm building plans used in extending aid to farmers, has become a member of A.S.A.E.; taken an active part in the work of its Structures Division; and in 1927 was chairman of its committee on structures research.

A Correction. It was erroneously stated in this section of our March issue that O. B. Stichter is a son-in-law of William Louden. Mr. Stichter was in no way responsible for this error and advises that he is not related to the Louden family.

# AGRICULTURAL ENGINEERING

**Established 1920**

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RAYMOND OLNEY, Editor

R. A. Palmer, Assistant Editor


## The Engineering Experiment Station Bill

AUTHORITIES in the land grant colleges seem to have suddenly come to a new realization of the connection between engineering and agriculture. Probably the conception has been brewing for some time and has only recently crystallized into visible form—the Engineering Experiment Station Bill now before Congress and the strong backing given it by the Land Grant College Association. President R. D. Hetzel of The Pennsylvania State College, speaking for the Association at hearings on the bill, expressed its viewpoint in these well-chosen words:

> "The Association is an executive body and represents the various presidents of these institutions. They have made very conscientious studies of the procedure which in their judgment would be best to carry forward this program, and it seems to them that we have now reached the point where we need to bring engineering to our aid. We are dealing with waste, we are dealing with mechanical processes all along the line. In chemistry, plant breeding, and with insect pests and plant and animal diseases we have made much progress. Now we have reached the point where we need the engineer to turn these processes into form so that we can deal with large quantities and deal efficiently with them."

That viewpoint on the part of those who direct the destinies of the land grant colleges is cause for great rejoicing by agricultural engineers.

To span the gap between engineering and agriculture a bridge of research is proposed. It would have a foundation, at one end, of federal encouragement, support, supervision and coordination through the U. S. Department of Agriculture; and, at the other end, of state initiative in analyzing engineering needs, maintaining engineering experiment stations and compliance with various other regulations in untying the federal purse strings. It would make up to $50,000 per year available to state engineering experiment stations for research for the advancement of agriculture and the mechanic arts, with the emphasis on agriculture assured. Its administration would be analogous to that of the Adams and Purnell funds for agricultural research.

A tendency of research which would be promoted by the bill is the approach to major problems by analyzing and subdividing them into smaller problems, each to be solved by the appropriate branch of science or engineering, and integrating the solutions. Research of this type is big business. In order that the funds provided may be spent wisely there must be close correlation between the various branches of science, between institutions, and between individual workers. The efficient conduct of engineering research of benefit to agriculture by a large number of widely scattered institutions, working on problems which interlock and overlap state and industrial boundaries, as contemplated in the bill, implies the development of a technique of coordination equal to the situation. It calls for agricultural engineers not only to do a certain part of the actual research, but to contribute to the coordination the benefit of their combined knowledge of agricultural problems and working conditions and of engineering methods and materials.

This proposed legislation hands agricultural engineers nothing directly except the greatest chance they could possibly ask for, to prove their worth. The agricultural engineering profession, backed by its quarter century of consistant progress, should welcome the test.

## Why A Non-Technical Meeting

ENRICHMENT of the lives and minds of agricultural engineer with new and renewed friendships, new sights and experiences, the viewpoints of nationally known men, and pictures of some of the big agricultural engineering problems of the immediate future is the aim and ideal to which the Meetings Committee of the American Society of Agricultural Engineers has held in planning and arranging this year's annual meeting program.

This is somewhat in contrast to previous annual meetings of the Society and to its technical division meetings held in late fall and winter. But it is in keeping with the season. When it is cold outdoors agricultural engineers can gather in comfortable hotel rooms and get intensely interested in highly technical questions. In late spring, as experience has shown, they react differently. Then they are more sociable, more visionary and inclined to spend more of their time outdoors. That is a proper humor for professional development along the non-technical lines indicated. We believe the Committee has chosen wisely in providing more time than ever before on the annual meeting program for subjects of general interest, nationally known speakers, demonstrations, sight-seeing and inspection trips.

## Noise

A SUB-COMMITTEE of the American Society of Mechanical Engineers is attempting to clarify the definition of sound; to determine what is harmful sound, what is a noiseless machine. The din, smoke and other nuisances incidental to certain engineering projects detract from their ultimate effectiveness in promoting the material comfort and welfare of mankind. The rattle of riveting hammers, the thundering of trains, the droning of airplanes exemplify an imperfect coordination of mechanism and purpose. The mechanical engineers hope to eliminate preventable noise and thereby improve this coordination. As engineering is applied to agriculture on an increasing scale, agricultural engineers will do well to give forethought to preventing similar situations before they arise. For example, the load factor on agricultural machinery is being increased with profit by night work during peak periods. And, while the sound of a tractor chugging steadily at its load might be music to the ears at noonday, the same would scarcely be true at midnight, to others than the operator.

This particular problem may easily be solved, but more difficult ones will be met. It will be a credit to agricultural engineers if they can see their work in the broad light necessary to forestall such cases of imperfect coordination before they become serious.

# A. S. A. E. and Related Activities

## TENTATIVE PROGRAM

**Twenty-Fourth Annual Meeting of the American Society of Agricultural Engineers Le Claire Hotel, Moline, Illinois, June 16-19, 1930**

**First Forenoon—6 to 12—Monday, June 16**

**College Division Session**

E. R. Jones, chairman, presiding

1. The Extension Man's Opportunity Compared to that of Another College Worker—Ivan D. Wood, University of Nebraska
2. An Agricultural Engineering Fellowship in Teaching Methods—Deane G. Carter, University of Arkansas
3. Agricultural Engineering Courses to Train Smith-Hughes Teachers—A. Carnes, Alabama Polytechnic Institute
4. Training Men for Research in Agricultural Engineering—J. B. Davidson, Iowa State College
5. Reports of Committees—Induction of the New Chairman—Reorganization of Committees

**Second Forenoon—9:30 to 12—Tuesday, June 17**

**General Session**

W. G. Kaiser, president, presiding

1. Meeting called to order by R. B. Lourie—vice-president, John Deere Plow Company—chairman of the Local Arrangements Committee
2. Welcome—by Mayor of Moline
3. Announcements—by F. A. Wirt, advertising manager, J. I. Case Company—chairman of Meetings Committee
4. President's Annual Address—W. G. Kaiser, agricultural engineer, Portland Cement Association
5. Scientific Research in Agriculture—Dr. A. F. Woods, director of scientific work of the U.S.D.A.
6. A Review of Agricultural Engineering Research—by R. W. Trullinger, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture

**Third Forenoon—9:30 to 12—Wednesday, June 18**

**General Session**

W. G. Kaiser, president, presiding

1. The World Engineering Congress—by H. B. Walker, agricultural engineer, University of California
2. Industrial Uses of Farm Products—by Dr. R. A. Clemen, associate director, Armour's Live Stock Bureau

**Fourth Forenoon—9.30 to 12—Thursday, June 19**

**General Session**

W. G. Kaiser, president, presiding

1. What is Here and Ahead in Agriculture—by Wheeler McMillen, associate editor, Country Home, New York, N. Y.
2. Symposium:—Row Crop Management—G. W. McCuen, agricultural engineer, Ohio State University, and others
3. Turning over of gavel to R. W. Trullinger, president-elect.

Monday and Tuesday afternoons will be given to field demonstrations; Wednesday and Thursday afternoons to sightseeing and factory inspection trips. In the evening of the first day the extension agricultural engineers will hold a session. The annual business meeting will be held Tuesday evening and followed by business sessions of the four technical divisions.

L. J. Fletcher, agricultural engineer, Caterpillar Tractor Company, will be toastmaster at the annual banquet on Wednesday evening. He is directing the plans for the entertainment and pleasure of the agricultural engineers on that occasion.

## Dates Set for Spring Meeting of Pacific Coast Section

SATISFACTORY arrangements have been made for holding a spring meeting of the Pacific Coast Section at Oregon State College, Corvallis, on May 2 and 3.

M. R. Lewis, vice-chairman of the Section, is chairman of the committee which is developing the program and making local arrangements. Machinery, lumbering, electrification, tillage and reclamation are all to receive the consideration of the various speakers.

## A.S.A.E. Joins International Congress of Agricultural Engineering

AN INVITATION to join the International Congress of Agricultural Engineering to be held at Liege, Belgium, in August of this year has recently been received and accepted by the American Society of Agricultural Engineers. President Kaiser has named H. B. Josephson, research engineer, department of farm machinery, Pennsylvania State College, to officially represent the Society at the Congress. Mr. Josephson will be traveling in Europe during the summer. W. C. Harrington, agricultural engineer, Portland Cement Association, has also announced his intention of attending the Congress.

Members of A.S.A.E. who are scheduled to submit papers include H. T. Barr, H. E. Murdock, Carlo Santini, F. C. Fenton, E. G. McKibben, H. H. Musselman, E. R. Gross, Dan Scoates, A. H. Hoffman and Hobart Beresford.

The program is divided into four sections—agricultural machinery, scientific organization of work, motor-culture and electricity. Listed for consideration in the agricultural machinery section are standardization of machinery and test methods, silos, seed testing stations, artificial drying of crops, and milking machines.

The scientific organization section will cover the "human factor" in agricultural work, hand tools, influence of machinery on labor needed in cultivation, manual labor in threshing and indoor farm jobs, influence of the tractor on labor requirements and influence of electricity on farm labor. Motor culture in the various countries, improvements of farm machines, new processes for the mechanical handling of soil and fuel problems are the subdivisions under the heading of motor culture. Electricity will be studied in connection with power, light, plowing and electroculture.

Chief patron of the Congress is H. M. the King of Belgium and the occasion is the International Exhibitions to be held in Liege and Antwerp. At least 16 different countries will be represented. The Belgian Minister of Agriculture is honorary president. Most of the contributions from the United States will be to the Section on Scientific Organization of Work.

## Congratulations, Pennsylvania!

THE agricultural engineering profession will enthusiastically receive the announcement that the board of trustees of The Pennsylvania State College at its meeting March 27 approved a four-year curriculum in agricultural engineering leading to the degree of bachelor of science in agricultural engineering.

According to word received from Ralph U. Blasingame, head of the department and chiefly responsible for this accomplishment, the board of trustees of their own volition changed the name of the department from "farm machinery" to "agricultural engineering."

Congratulations to Pennsylvania, and congratulations to Prof. Blasingame!

## Election of A.S.A.E. Officers

THE election of officers of the American Society of Agricultural Engineers for the year 1930-31 recently completed by letter ballot of the voting members, resulted as follows:

President, R. W. Trullinger, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture

First Vice-President, W. H. Worthington, engineer, Gleaner Combine Harvester Company

Second Vice-President, Ben D. Moses, associate professor of agricultural engineering, University of California.

Treasurer, Raymond Olney

Councilor, Lewis A. Jones, drainage engineer, U. S. Department of Agriculture

Nominating Committee, O. B. Zimmerman, chairman; C. O. Reed, and E. A. White.

These officers will take office following the 24th annual meeting of the Society at Moline, Illinois, June 16, 17, 18, and 19, 1930.

## Personals of A.S.A.E. Members

**W. A. Harper** has been promoted from the agricultural sales, eastern division, with headquarters at Peoria, Illinois. sales staff of the western division of the Caterpillar Tractor Company, to the position of supervisor of agricultural

## New A.S.A.E. Members

**Charles F. Bateholts**, farm electrification adviser, General Electric Co., Schenectady, N. Y.

**Chester L. Berggren**, instructor in farm buildings, University Farms, St. Paul, Minn.

**Harry E. Besley**, graduate student, University of Maryland, College Park, Md.

**Herbert S. Eastwood**, sales manager, The De Laval Separator Co., New York, N. Y.

**Ralph W. French**, director of agricultural sales, French Tractor & Equipment Company, Springfield, Ill.

**James G. Klemgard**, wheat ranch manager, Pullman, Wash.

**Homer C. Mauer**, junior agricultural engineer, U. S. Department of Agriculture, Washington, D. C.

**Harlo A. von Wald**, assistant agricultural engineer, United Fruit Company, Tiquisate, Estacion Rio Bravo, Guatemala, Central America.

**Clyde Walker**, assistant professor, Oregon State College, Corvallis, Ore.

## Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the March issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

**John Bird, Jr.**, advertising manager, The Wheat Farming Company, Topeka, Kan.

**George C. Brooks**, manager of rural department, Empire Gas & Electric Co., Waterloo, N. Y.

**Wilbur Drake**, graduate fellow, Iowa State College, Ames, Ia.

**Albert R. Fairchild**, general station sales engineer, Westinghouse Electric & Mfg. Co., Glenside, Pa.

**Albert B. Hanse**, engineer, J. I. Case Co., Racine, Wis.

**Fred W. Hawthorn**, farmer, Castana, Ia.

**Louie T. Jessup**, associate drainage engineer, U. S. Department of Agriculture, Yakima, Wash.

**David A. Milligan**, assistant agricultural engineer, Cleveland Tractor Co., Cleveland, Ohio.

**Charles F. Moreland**, in charge of water heater sales, Edison General Electric Appliance Co., Chicago, Ill.

**Robert S. Overstreet**, agricultural engineer, Idaho Power Co., Boise, Ida.

**Frazier Rogers**, professor of agricultural engineering, University of Florida, Gainesville, Fla.

**Louis C. Thomsen**, assistant professor of dairy husbandry, University of Wisconsin, Madison, Wis.

**Orville J. Trenary**, instructor, University of Nebraska, Lincoln, Neb.

# Employment Bulletin

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only Society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available' section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested. Copy for notices must be received at the headquarters of the Society not later than the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. There is no charge for this service.

## Men Available

AGRICULTURAL ENGINEER, formerly director of experimental station and government agricultural and import expert of Kingdom of Yugoslavia, speaking all Slav languages fluently, wants position in agricultural college, commercial farm or dairy plant; would also like connection in a manufacturer's export department. Russian. Married. Age 31. Willing to go anywhere. MA-168.

AGRICULTURAL ENGINEER now employed as a teacher of vocational agriculture desires a position as teacher or research worker in agricultural engineering, preferably at a southern college. Have had two years experience in college teaching and while in present work have had outstanding experience in farm shop work and farm buildings. Age 33. Married. MA-170.

AGRICULTURAL ENGINEER also trained in accounting, five years factory, selling, and office experience with large manufacturer. Prefers connection with engineering firm having some problems in accounting or finance, or with a concern engaged in the financing of agricultural projects. MA-171.

AGRICULTURAL ENGINEER with 15 years experience in irrigation, drainage, farm motors, farm machinery and pumping desires a change of location to the west or southwest. MA-173.

## Positions Open

AGRICULTURAL ENGINEER wanted to fill position as instructor or assistant professor in the department of agricultural engineering of one of the land grant colleges of the Northwest. A recent graduate in agricultural engineering qualified for rural electrification and power farming with farm and practical experience is desired. Opportunity offered for research work and for participation in experiment station and extension service projects. Teaching work required will be largely in service courses in agricultural engineering. Minimum salary $1800 to $2100 per year on twelve months basis with one month vacation. PO-155.

AGRICULTURAL ENGINEER wanted by agricultural engineering department of state college in northwest United States to handle teaching and experiment station work in farm machinery and tractors. The successful applicant will also be required to do some teaching in farm shop including forge work and dairy mechanics. PO-168

AGRICULTURAL ENGINEER wanted to fill position as instructor or assistant professor in the department of agricultural engineering of one of the land grant colleges of the Northwest. A recent graduate in agricultural engineering qualified for land reclamation, especially irrigation and drainage, with irrigation farming and project management experience desired. Opportunity offered for research work and for participation in experiment station and extension service projects. Teaching work required will be largely in service courses in agricultural engineering. Minimum salary $1800 to $2100 per year on twelve months basis with one month vacation. PO-169.

JUNIOR ENGINEER wanted by eastern utility for electric power sales in rural communities, including small commercial development. Should have an agricultural background and be a graduate of a recognized technical college. Good opportunity for advancement. Please enclose recent picture and state age, education, experience and salary desired. PO-170.